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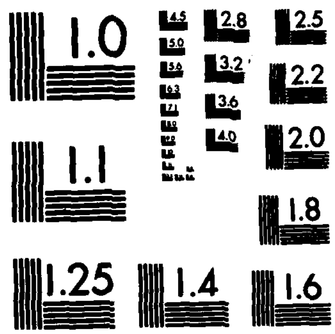
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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

MULTIVARIATE ANALYSES OF AFLOAT SUPPLY
PERFORMANCE AND AIRCRAFT READINESS DATA

by

Stephen Wayne Guion

October 1982

Advisor: Donald P. Gaver

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The impact of afloat Supply Support Effectiveness on Aircraft Readiness has become a topic of increased visibility and attention to military planners and policy-makers, yet relatively few research analysis efforts have been directed toward discovering which elements of aircraft carrier supply performance are the most closely related to aircraft Mission Capability concepts and measures.

In this report, the logistic support data base maintained by the Force Supply Staff of COMNAVAIRPAC is analyzed. Using well-known multivariate regression analysis techniques, the relationships between the performance variables and aircraft readiness variables are examined to find a statistically significant combination of variables that are representative of both aviation supply support and aircraft readiness. Based on the results presented, the conclusion is made that the number of off-ship requisitions (backorders) is the variable which provides the direct link between aircraft readiness and supply performance.

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# Multivariate Analysis of Afloat Supply Performance and Aircraft Readiness Data

by

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| | |
|---|---|
| ACFT IN RRS | - Total Aircraft in Reporting Status |
| AD | - Number of AVCAL Demands |
| AG | - AVCAL Gross Effectiveness |
| AMR | - Aircraft Material Readiness Report |
| AN | - AVCAL Net Effectiveness |
| ANOVA | - Analysis of Variance |
| AR | - AVCAL Inventory Range |
| ASO | - Aviation Supply Office |
| ASR | - Afloat Supply Readiness Report |
| AVCAL | - Aviation Consolidated Allowance List |
| AVLI | - Number of AVCAL Line Items |
| AWM | - Awaiting Maintenance |
| AWMC | - Total number of repairable component items in AWM status on the last day of a month |
| AWM15 | - Total number of repairable components in AWM status on the last day of a month that have been in that status for 15 days or more |
| AWP | - Awaiting Parts |
| AWPC | - Total number of repairable components in AWP status on the last day of the month |
| AWPR | - Total number of repair part requisitions that are still outstanding on the last day of a month |
| AWP30 | - Total number of repairable components in AWP status on the last day of a month that have been in that status for 30 days or more |
| AWP60 | - Total number of AWP requisitions outstanding on the last day of a month that have been on order for 60 days or more |

| | |
|---|---|
| AX | - AVCAL Inventory Depth |
| BCM | - Beyond Capability of Maintenance |
| BLUE | - Best-Linear-Unbiased-Estimator |
| CD | - Number of CLAMP Demands |
| CG | - CLAMP Gross Effectiveness |
| CLAMP | - Closed Loop Aeronautical Management Program |
| CLLI | - Number of CLAMP Line Items |
| CN | - CLAMP Net Effectiveness |
| COM | - Components Inducted |
| COM AWM | - Number of inducted components which were in AWM status for more than three days during the month |
| COM AWP | - Number of inducted components which were in AWP status for more than three days during the month |
| COM RFI | - Number of components repaired during the month |
| COMNAVAIRPAC | - Commander U.S. Pacific Fleet Naval Air Force |
| COSAL | - Coordinated Shipboard Allowance List |
| CR | - CLAMP Inventory Range |
| CRF | - Component Repair Factor |
| CV | - Aircraft Carriers |
| CV1-CV5 | - Labels used to identify aircraft carriers studied in this report |
| CX | - CLAMP Inventory Depth |
| FMC | - Full Mission Capable |
| FMC ACFT | - Total Full Mission Capable Aircraft |
| FMC RATE | - Ratio of FMC ACFT to ACFT IN RRS |
| G | - Gross Effectiveness |
| IDA | - Interactive Data Analysis Statistical Package |
| IRAM | - Improved Repairable Asset Management |

| | |
|---|---|
| LHA | - General Purpose Assault Ship |
| LPH | - Amphibious Assault Ship |
| MC | - Mission Capable |
| MC ACFT | - Total Mission Capable Aircraft |
| MC RATE | - Ratio of MC ACFT to ACFT IN RSS |
| MM | - AWM Rate; Ratio of COM AWM to COM |
| MP | - AWP Rate; Ratio of COM AWP to COM |
| MR | - Repair Rate; Ratio of COM RFI to COM |
| MSFA | - Material Support Factor-Aviation |
| N | - Net Effectiveness |
| NALI | - Number of Authorized Line Items |
| NALI RFI | - Number of Authorized Line Items in the inventory group with at least one Ready-For-Issue unit on hand |
| NALI RFI GE ROP | - Number of Authorized Line Items in the AVCAL with RFI units on hand greater than or equal to the Reorder Point |
| NALI 100% RFI | - Number of Authorized Line Items in the inventory group that have 100 percent of their authorized quantity on hand in RFI condition |
| NAVAIRSYSCOM | - Naval Air Systems Command |
| NC | - Not Carried |
| NIS | - Not in Stock |
| NMC | - Not Misison Capable |
| NMCM | - Not Mission Capable-Maintenance |
| NMCS | - Not Mission Capable-Supply, also used to describe requisitions causing an NMC status |
| NPLI | - Number of POOL Inventory Items |
| P/NMCS | - Daily average each month of PMCS and NMCS requisitions outstanding in the supply system; supply performance variable |
| PD | - POOL Demands |

| | |
|---|---|
| PE | - POOL Effectiveness |
| PMC | - Partially Mission Capable |
| PMCS | - Requisitions Causing a PMC Status |
| POLI | - Number of POOL Line Items |
| POOL | - Rotatable Pool Inventory Group |
| PR | - POOL Inventory Range |
| PX | - POOL Inventory Depth |
| PZBR | - POOL Zero Balance Rate; Ratio of ZERO RFI to NPLI |
| R | - Range; Ratio of NALI RFI to NALI |
| RFI | - Ready-For-Issue |
| RRS | - Readiness Reportable Status |
| SUADPS | - Shipboard Uniform Automated Data Processing System |
| TOT AUTH DEM | - Number of demands placed during a month |
| TOT DEM | - Total number of demands placed during the same month for material in the applicable inventory group |
| TOT ISS | - Total number of Issues made during a given month from on hand material in an inventory group |
| X | - Depth; Ratio of NALI 100% FRI to NALI |
| ZERO RFI | - Number of POOL line items with zero FRI material on hand |

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# I. INTRODUCTION

## A. HISTORICAL BACKGROUND

The Commander of the U.S. Pacific Fleet Naval Air Force (COMNAVAIRPAC) is tasked with the primary function of training all Naval Air units in the Pacific to develop their operational readiness and combat efficiency for service with the U.S. Third and Seventh Fleets. All aircraft carriers, naval aircraft, and aviation units assigned to the Pacific Fleet come directly under the administrative control of COMNAVAIRPAC. This requires all assigned aircraft carriers to make periodic readiness reports to COMNAVAIRPAC during deployments to the Pacific or Indian Ocean and also during operational periods of pre-deployment work-ups. The data collected from the various reports encompass a wide range of effectiveness and readiness indicator variables. These variables are utilized to qualify and to quantify aircraft carrier performance at the departmental level. Depending upon their relative importance to the command, variables are transmitted to COMNAVAIRPAC daily, weekly, or once or twice a month.

The periodicity of the many reports, combined with the constraints placed upon both the time and the personnel available to produce them aboard ship, prompted a recent study at COMNAVAIRPAC. This study focused on the possibilities of reducing or eliminating some of the carrier reporting requirements. The Force Supply Officer (Code 40), who administers the supply activities of COMNAVAIRPAC, and the Force Supply Staff became particularly involved in this study. This was partially due to the simple fact that a large number of the different readiness reports

contained at least one or more supply-related performance data variables. A second reason for involvement was Code 40's goal to increase afloat supply support effectiveness and aircraft readiness through efficient and effective Staff data collection and monitoring techniques.

Several tasks were established and assigned to the Code 40 Staff in order to accomplish their study. These tasks included:

1. Identification of the data variables that were currently being collected and utilized by Code 40.

2. Identification of additional data variables which would improve the methods of performance evaluation.

3. Identification of the data variables that were of little or no value.

4. Creation of an automated data base system for the collection and utilization of the data variables.

The completion of these tasks produced two major improvements for the Code 40 Staff. One of these was the creation of an automated logistic support data base from existing manual records and files. The second improvement was a revision of the aircraft carrier supply reporting requirements. This revision consolidated the key supply support effectiveness variables into one twice-monthly report. This provided a simple and efficient input source for updating and expanding the data base.

Having accomplished this, the Code 40 Staff wanted to provide high-level management with a meaningful and accurate method to observe and evaluate afloat supply support trends for one aircraft carrier, or to compare one carrier with another, without assimilating large amounts of data. This was accomplished by combining several of the performance variables to create three artificial variables. These variables were labeled Support Factors.

The Support Factor variables describe three different areas that generally represent supply support effectiveness. In fact, the Support Factors are an attempt to reduce the number of variables that might conceivably represent supply support effectiveness. Two of the Support Factors deal with material support in the form of aircraft parts and ship parts. The third Support Factor is a variable created to measure the aggregate performance level of the aviation component repair facility on board each aircraft carrier. These are explained in detail in Section II.

## B. THE NATURE OF THE PROBLEM

### 1. Aircraft Readiness

The generally accepted indicators of aircraft readiness within the Naval Aviation community are the Mission Capable Rate (MC) and the Full Mission Capable Rate (FMC). In simple terms, an aircraft is considered mission capable if it can perform at least one of its assigned missions. It is full mission capable if it can perform all of its assigned missions.[1] If an aircraft does not fall into one of these two categories, it normally is not safely flyable and is considered to be "hard down" or Not Mission Capable (NMC). An aircraft may be in NMC status for one or both of two reasons. First, the aircraft may require scheduled or unscheduled maintenance in order to return it to a flyable status. This condition is referred to as Not Mission Capable-Maintenance (NMCM). The second situation occurs when an aircraft is in NMC status because of the absence of one or more parts. This is known as Not Mission Capable-Supply (NMCS).

[1]These variables are defined further in Section II.

### 2. Problems With General Models for Aircraft Readiness

In view of the variables used to categorize the various states of aircraft readiness, it is clear that the level of readiness achieved by any aircraft carrier should be directly influenced by the performances of both the afloat supply activity and the afloat maintenance activity. Ideally, it would be desirable to have a model that could utilize the performance data collected from both Maintenance and Supply to predict aircraft readiness, namely: MC and FMC. This is the type of model that the Code 40 Staff actually wants. A model such as this would enable them to monitor the progress of deployed carriers and identify potential supply problem areas that require the Staff's assistance or guidance.

Attempts at creating a general model to explain aircraft readiness are limited in a statistical sense by at least two factors. One of these is the assortment of variables currently used to measure the different areas of performance. Even though a great many variables have been defined and recorded by various commands, it is quite likely that a revised definition of one or more variables could clarify interpretation of the data. There may also exist performance variables that are either unknown or currently believed to be unimportant, which actually would be very good at explaining aircraft readiness. As is often the case, an "unknown" variable is "discovered" to be some combination of several of the known variables, thus reducing the overall number of variables required. The bottom line here is that one is often stuck with just the variables at hand, and they normally turn out to be either too many or too few.

The second factor, which causes even greater difficulty, is the impact on aircraft readiness from areas uncontrolled by Supply. In a statistical model, this is known as noise, error, or unexplained variance. From the standpoint of the Code 40 Staff, this could be partially viewed as "the data everyone else is collecting." This is not entirely prohibitive to modeling, however, since some of the readiness-influencing data variables outside the cognizance of the Code 40 Staff are available to them. Data variables covering areas such as Flight Operations, Ground Support Equipment, Personnel Strength, as well as Maintenance, can be retrieved as easily as their own Supply data. The true uncontrollable areas that create noise in a general model for readiness occur as intangibles to the Supply effort.

It has often been observed that what works for one aircraft carrier does not work as well for another. Although this usually happens where there is no uniform procedure established for all carriers to follow, a proven system may still fail to perform within acceptable limits because of the influence of "intangibles." Intangibles can include: the level of training, intelligence, or ability of personnel; the experience and expertise of management; or the communication and cooperation between departments. Aircraft readiness could also be influenced by intangibles as subtle as the confidence and attitude of the ship's crew. These are the kinds of things that are different on each ship and change with each deployment. There exist additional influential factors which cannot exactly be considered intangible, but they are equally difficult to utilize in any quantitative sense. Some of these are: the locations where deployments occur, the length of at-sea and

in-port periods, the number and types of aircraft assigned, the age of both the operating and the support equipment, and the actual size or tonnage of the ship. With all that is known and measured, trying to fully explain any small part of what is not known continues to be a complex problem.

3. The Problem at Hand

There remains the problem of what to do with the data that is currently collected. Just as there is no single indicator variable that can be agreed upon to precisely measure levels of Force operational readiness, the definition of a variable which can represent the concept of supply support effectiveness is equally obscure. The set of Support Factor variables developed by the Code 40 Staff is an attempt at reducing the set of data variables believed to be indicative of supply support effectiveness. The problem with these Support Factors is that they fail to relate the supply data variables with aircraft readiness.

The Support Factors are simply the weighted averages of those indicator variables believed to be the most significant and useful in describing supply support effectiveness. The weight assigned to each variable depends upon what the variable represents. For example, a variable that measures actual performance, such as the ability to fill demands for material from inventory, is given more weight than a variable that measures just the potential to do the same thing, e.g., inventory range or depth. Variables believed to have a negative influence on performance are correspondingly given a negative weight.

Although the Support Factors provide a concise means of performance comparison, they do not actually contribute to performance evaluation.

The composition of each Support Factor is based on little more than a subjective analysis of the data variables. As they are currently defined, the Support Factors are useful only as a qualitative comparison of aircraft carriers. They have no reference standards from which to detect individual carrier efficiency or deficiency. The problem, then, is to identify a subset and combination of the supply performance variables currently collected which, by virtue of their relative influence on aircraft readiness, constitute a meaningful indicator of supply support effectiveness.

## C. OBJECTIVE

This research effort analyzes the logistic support data base maintained by the Force Supply Staff of COMNAVAIRPAC. The goal here is to improve the aircraft carrier supply performance monitoring and evaluation processes by creating a useful and meaningful indicator of aviation supply support effectiveness. Using well-known multivariate regression analysis techniques, the relationships between the performance variables and the readiness variables, MC and FMC, are examined to find a statistically significant combination of variables that are representative of both aviation supply support and aircraft readiness. Finding a proper subset of variables which explain MC/FMC trends may provide a basis for reducing the reporting requirements of deployed aircraft carriers even further. At the same time, this would distinguish those areas of the afloat supply activity where additional management would be most beneficial.

## D. SCOPE

Several well-known data analysis techniques have been utilized while in pursuit of the objectives of this study. This report is written with the intent that it be useful to both the reader who is familiar with the techniques as well as the reader who is not. This report presents the techniques used to analyze the data base and lists some of the results that were found to be statistically significant or noteworthy. The theoretical aspects and statistical background of the analysis methods used here are not discussed in this report to any large extent, nor are the relative merits of each method evaluated. This analysis is simply an application of the various techniques rather than an explanation of them. Readers who are unfamiliar with the techniques but wish to know more about them are encouraged to examine any of the several good textbooks that cover multivariate and other data analysis techniques. A few of these are listed in the Bibliography.

## E. PREVIOUS LITERATURE AND STUDIES

During the preliminary stages of this study, initial and secondary literary searches were performed with the aid of the Defense Technical Information Center and the Defense Logistics Studies Information Exchange in order to identify previous research efforts which include analyses of performance variables similar to those examined in this paper. The logic of this is quite simple. If any previous groundwork has already been established in the field of study, it is of natural benefit to an analyst to draw from this information. Prior results, conclusions, or recommendations could possibly indicate directions from which to approach the current data, or might point out pitfalls to avoid.

Unexpectedly, the literary searches revealed very few documented studies of aircraft readiness, and located no previous studies which examine the relationships between aircraft readiness and supply performance at the aircraft carrier level. The overwhelming majority of applicable literature is concerned with general readiness models or concepts, and there appears to be no documented prior research that covers the areas examined in the present study. Other studies that do include aircraft readiness in their analyses have dealt primarily with the influential effects of: (1) cannibalization actions, (2) component repair actions (maintenance), (3) number of flight hours or sorties flown by aircraft, and (4) funding or budget constraints.

For example, Monahan [Ref. 1] has proposed an evaluation model for the purpose of relating logistics system performance to operational readiness, but his methods are directed toward readiness evaluation at the Task Force level. In his report, supply performance is recognized as one of the many elemental factors that represent "the bottom level in the readiness hierarchy structure." [Ref. 2] Monahan further explains that his proposed concept for overall readiness evaluation requires the development of "Support Factor models used to establish readiness estimates for ship types in each of the ship resource areas as functions of the effectiveness of the necessary support activities."[2] [Ref. 3] The term "ship resource areas" encompasses a broad spectrum of resources that, in addition to the provisioning and resupply of equipments and spares, also includes personnel resources, fuel resources, and mission-expendable

[2]Emphasis added.

resources (weapons). This model is developed from a "macro" point of view, and the study offers no descriptions of how the inputs, (i.e., supply support effectiveness) might be applied to each Support Factor model.

In an analysis of aviation activity variables based upon data from non-deployed squadrons, Hensley [Ref. 4] concludes that operational readiness (akin to aircraft readiness) is strongly associated with monthly flight hours and also with the monthly number of parts that are diagnosed by maintenance personnel as non-operable, removed from aircraft, and subsequently determined not to be broken. These results were obtained from analyses of a data base that did not contain any supply-controlled variables, and no consideration was made for their possible influence on readiness. The correlation analyses of the data base did suggest an analysis technique that is used in the current study.

An analysis of readiness performed by Macri and Phillips [Ref. 5] considers the length of time to resupply material from a Stock Point (Supply System Response Time) and also examines the effect of the total cost of inventory spare parts on readiness levels. Their results indicate that increased delays in response time have a significant negative impact on readiness. These delays correspond to the length of time it takes requisitioned material to arrive on board from an off-ship source. There is a variable in the data base of the current study that documents these off-ship requisitions. This variable is the total number of Partially Mission Capable and Not Mission Capable Supply Requisitions (P/NMCS), and it reports the daily average each month of off-ship requisitions outstanding in the Supply System. Although this variable is not measured to

reflect delays in supply response, it will be seen later in this report that it also is negatively related to aircraft readiness.

Macri and Phillips also conclude that reductions in the inventory levels (based on total inventory cost) create a quantitative decrease in readiness while increases in inventory beyond established baselines result in relatively small increase in readiness. The result is based on ". . . the fact that insufficient [repairable] spares cause excessive [aircraft] downtime, but addition of redundant spares cannot improve readiness beyond the limitations imposed by maintenance downtime." [Ref. 6] In other words, once a certain threshold depth of repairable stock is reached, the amount of time it takes the repair activity to fix the repairable items has a greater influence on readiness than does the number of repairables on hand.

One final study warrants mention. This study is currently in its final stages and has been conducted by the Air Force Logistics Management Center located at Gunter Air Force Station, Alabama. Using data from two Air Force Bases, the study attempts to identify measures of shore-based supply performance that have a statistically significant correlation with measures of operational capability. An untitled final report of the study has not been released, but portions of the analyses and working notes were forwarded to the author at his request. Unfortunately, the results of the study are inconclusive, and the accompanying documentation offered no new insights into the problem at hand.

# II. THE DATA BASE

## A. BASIC DESCRIPTION

The data base used in the analyses of this study contains a total of 32 variables. These include the two aircraft readiness response variables: MC and FMC, 28 supply and maintenance performance variables, and two of the three "Support Factor" artificial variables. Each of these variables is explained in detail in this chapter. These data were collected over a 13-month period by the Code 40 Staff of COMNAVAIRPAC, and they include observations from five different Pacific Fleet aircraft carriers. The identity of each ship involved in the analyses has been omitted in this report for security reasons; the aircraft carriers have been named CV1 through CV5 in order to preserve their anonymity. The numbering of the ships is an arbitrary assignment based on the number of observations available from each ship. These totals are summarized in Table 1. The observed data values pertaining to each aircraft carrier are tabulated in Appendix C.

TABLE 1

SAMPLE SIZE OF OBSERVATIONS AVAILABLE PER AIRCRAFT CARRIER

| Aircraft Carier | Number of Monthly Observation Sets |
|---|---|
| CV1 | 4 |
| CV2 | 4 |
| CV3 | 6 |
| CV4 | 7 |
| CV5 | 11 |
| TOTAL | 32 |

## B. INPUT SOURCES TO THE DATA BASE

In the introduction of this report, it was pointed out that the existing automated Code 40 data base was created from existing records and files. The data base is currently updated on a monthly basis using inputs from the deployed aircraft cariers. These inputs are transmitted to COMNAVAIRPAC by two types of message reports: the Aircraft Material Readiness (AMR) report and the Afloat Supply Readiness (ASR) report.

### 1. Aircraft Material Readiness Report

The AMR report is the input source of the readiness variables, MC and FMC. It is also the source document for the supply performance variable, P/NMCS, discussed later in this section. The AMR report summarizes aircraft flight operations and other aviation-related events which occur on board an aircraft carrier each day. It also recaps the readiness posture of the embarked airwing following the completion of the day's events. Some of this information is classified, therefore the AMR report is transmitted to COMNAVAIRPAC via Confidential message. This message is prepared each day by the Airwing Department of the ship and is constructed from daily inputs of the embarked squadrons. Additional inputs are obtained from the ship's Supply and Maintenance Departments. Although supply-related variables are included in the daily AMR report, its main purpose is reporting the airwing readiness and overall operational performance rather than reporting supply performance.

### 2. Afloat Supply Readiness Report

The ASR report is the primary instrument for reporting supply support performance variables and is the data source for the remaining 27 supply and maintenance variables used in this study. This is the

message report that was introduced in Section I as the Code 40 revision which consolidated the supply reporting requirements. Most of the data for the ASR report is collected from the paperwork that is generated from daily afloat supply and maintenance transactions, e.g., requisitions, receipts, repairs, backorders, cancellations, et cetera. These data are compiled by the Shipboard Uniform Automated Data Processing System (SUADPS). The SUADPS hardware and software are operated and maintained onboard each aircraft carrier by the Supply Department. Twice each month the data values of the SUADPS-generated supply performance variables are retrieved from the system. These variables are included with other non-SUADPS-generated performance indicators in order to prepare the ASR report, which is then transmitted to COMNAVAIRPAC via Unclassified message.

## C. AIRCRAFT READINESS CONCEPTS

At this point, the reader should be familiar with the definitions of the aircraft readiness variables, Mission Capable (MC) and Full Mission Capable (FMC). Because these variables represent the focal point of this study, they are reintroduced in this section and explained in detail.

### 1. Reporting Status

The reporting custodians (squadrons) of operational aircraft are accountable to report the readiness of each assigned aircraft for 24 hours per day. A requirement for including any individual aircraft in the computation of readiness data is that the aircraft must be in a Readiness Reportable Status (RRS). If an aircraft is not reportable, it is omitted from the calculations of MC and FMC.

2. Mission Capability

Each type of aircraft in use by the Navy is designed and built with the purpose of performing one of several basic missions. These missions vary in scope, and each aircraft is designated or categorized by the basic mission it performs, e.g., attack, fighter, helicopter, etc. The basic mission of any aircraft is subdivided into several primary missions, based upon the squadron to which the aircraft is assigned. These missions may be as complex and demanding as the tracking of multiple sonar contacts by an S-3A aircraft or as simple as the return flight to the home Naval Air Station at the end of deployment.

As long as an aircraft is safely flyable and capable of performing one or more (but not necessarily all) of its primary missions, it is considered to be Mission Capable (MC). The aircraft must have ready the mission-essential subsystems necessary for the performance of one or more of the primary missions. If the aircraft cannot meet these criteria, it is considered to be Not Mission Capable (NMC).

3. Factors Affecting Mission Capability

By definition, an aircraft may become NMC for only two possible reasons. First, if the aircraft is "down" because of the need for scheduled or unscheduled maintenance, it is in a Not Mission Capable-Maintenance (NMCM) condition until the maintenance action is completed. Second, the aircraft may become NMC because one or more of the aircraft parts critical to either the safety of flight or the mission essential subsystems breaks or is removed. The reader will recall from Section I that this condition is referred to as Not Mission Capable-Supply (NMCS). The term, NMCS, is also used to describe the requisitions for the material or parts which

cause the NMC condition. Finally, the situation may occur in which an aircraft falls into both categories simultaneously. If the maintenance action(s) cannot be performed without the required part(s), the NMCS category is reported.

4. Partial and Full Mission Capability

Not all aircraft parts deficiencies or maintenance actions cause an NMC condition. When an aircraft is capable of performing one or more of the primary missions, but with some limitation in operational capability due to parts or maintenance, it is considered to be Partially Mission Capable (PMC). Aircraft reported in this condition, in the final analysis, fall into the MC category. The noteworthy point here is that the PMC condition is what prevents MC aircraft from attaining Full Mission Capacity (FMC) status.

An FMC aircraft, then, is one which does not have any mission degrading requisitions or maintenance actions outstanding. In other words, all mission-essential equipment and components in an FMC aircraft should function as designed.

5. Aircraft Readiness Indicator Variables

Because the operational status of any aircraft may change from hour to hour on an aircraft carrier, a "head count" of aircraft and their status is conducted by each squadron once a day. The counting process is scheduled at the same point in time each day in order to provide consistency in the reporting process. The results of the squadron counts are totalled to give the following values:

1. Total aircraft reporting status (ACFT IN RRS),
2. Total MC aircraft (MC ACFT), and
3. Total FMC aircraft (FMC ACFT).

Using these values, the MC and FMC rates are determined as follows:

$$\text{MC RATE} = \frac{\text{MC ACFT}}{\text{ACFT IN RRS}}, \tag{1}$$

$$\text{FMC RATE} = \frac{\text{FMC ACFT}}{\text{ACFT IN RRS}}. \tag{2}$$

These percentages are the aircraft readiness values reported daily by the AMR reports. The reader should note that an aircraft must be Mission Capable in order to be Full Mission Capable. FMC ACFT, therefore, is a subset of MC ACFT, and the value of the FMC rate will always be less than or equal to the MC rate.

## D. INVENTORY GROUPS

The majority of the variables in the data base are indicators of the actual or potential performance involving the inventories of components, repair parts, and consumable items on board each aircraft carrier. There are two major divisions of an aircraft carrier's parts inventory, which are discussed in this section. Additionally, there are two subcategories of inventory items that are much smaller in terms of range and depth of material but are highly visible and important to inventory management. A brief description of these different classifications of inventories is presented here in order that the reader may achieve a better understanding of what each performance variable is measuring.

In order to provide the support necessary to operate in an environment of minimum or potentially no replenishment for a given time period, the Navy uses the <u>Allowance List</u> concept. An allowance list is a document which specifies by stock number or part number the equipments, repair parts, and supporting materials necessary for the efficient operation of the ship and the aircraft assigned. There are several types of allowance

lists for aircraft carriers. However, the two that constitute the bulk of inventory items are the COSAL and the AVCAL.

1. Coordinated Shipboard Allowance List (COSAL)

The COSAL is an authoriative document which indicates the items and their quantities which a ship should have on hand to achieve a self-supporting capability for a prescribed period. This allowance list is tailored to each ship, and the number of line items in the COSAL inventory may vary from 20,000 to 40,000 items depending on ship size. The items in the COSAL, however, apply only to ship-related material and operations, there are no aviation materials in this group.

2. Aviation Consolidated Allowance List (AVCAL)

The AVCAL is the aviation equivalent of the COSAL. This allowance list indicates the authorized items and quantities of repairable and consumable material which should be on board to achieve a self-supporting capability for the support of assigned aircraft for a prescribed period. Like the COSAL, the AVCAL is tailored to each aircraft carrier. The inventories of AVCAL material on the ships used in this study vary between 30,000 and 50,000 different line items.

3. Closed Loop Aeronautical Management Program (CLAMP)

CLAMP is an element of the Improved Repairable Asset Management (IRAM) Program. It is an intensified repairables management program designed to achieve optimum utilization of expensive assets. CLAMP is applicable to a small but significant fraction of aviation-related repairables used on embarked first-line aircraft and support systems. CLAMP items are given intensive local management by field representatives using one-for-one exchange, serialized component tracking, and dedicated

storage sites that are segregated from other non-CLAMP inventory items. The inventory of CLAMP line items is small when compared with the AVCAL inventory. The number of different line items on board the ships of this study varies between 600 and 3,000 items.

4. Rotatable Pool (POOL)

The rotatable pool is a selected subset of inventory items consisting of CLAMP and non-CLAMP repairables. These locally-repairable items have been documented as being high-usage items, and this is the primary criterion for their selection as POOL items. The range of these items is normally limited to components that must be available immediately to shorten repair time. POOL items are also segregated from other inventory items, and they are positioned in a convenient location in order to provide quick access to the material. This is the smallest group of inventory items applicable to this study, and the number of POOL line items onboard the ships of this study varies between 130 and 290 items.

5. Overlap of Inventory Groups

The records and data files of the AVCAL and CLAMP inventories are maintained as separate data bases. Theoretically, all aviation-related materials, including CLAMP, are part of the AVCAL inventory. Because CLAMP is a special inventory-management program, all transactions that involve CLAMP material are coded to enable independent documentation by SUADPS programming.

The POOL inventory, on the other hand, is composed entirely of AVCAL and CLAMP items. Either a POOL item is in the AVCAL inventory, or it is a CLAMP item. Approximately 60 percent of the line items in the POOL inventory are CLAMP-designated items. POOL items are also coded in

order to identify POOL transactions, but these records are not excluded from the AVCAL and CLAMP files. For example, if a demand is recorded for a POOL item, a corresponding demand is also established in the applicable AVCAL or CLAMP records. Because of this intersection among inventory groups, the POOL performance variables are expected to be quite correlated with those of AVCAL and CLAMP.

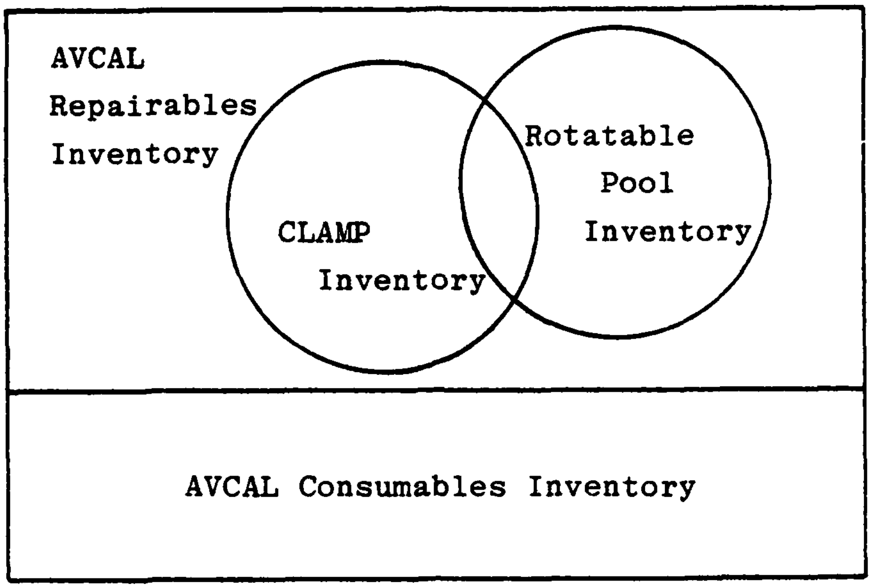
The distinction between the physical structure and the record-keeping structure of the inventory groups may be visualized by the Venn diagrams of Figure 1. Figure 1a shows the relationships between the inventory line items according to their actual authorized Allowance List classification. Figure 1b shows the intersection and overlap of the records and files that are maintained for each inventory group.

## E. INVENTORY PERFORMANCE VARIABLES

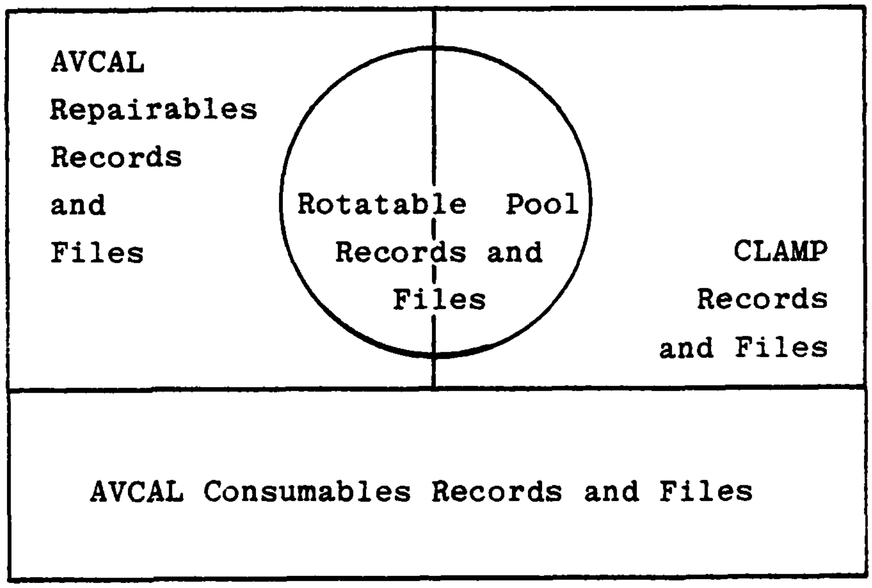
The majority of the variables in the data base are performance indicators which track various operating characterisitcs of the AVCAL, CLAMP, and POOL inventory groups. This is not surprising since overall performance of any aircraft carrier Supply Department is measured largely by its ability to provide ready-for-issue (RFI) replacement parts to the embarked squadrons and RFI repair parts to the ship's maintenance activity. In this section, the different methods of measuring inventory capability and performance are examined.

### 1. Number of Line Items

The number of line items in an inventory group is simply the total number of different repairable components and piece parts, identified by part number or stock number, that are included in the authorized allowance lists. The AVCAL and CLAMP listings are tailored to each aircraft




1a. Physical Structure




1b. Record-Keeping Structure

Figure 1. Venn Diagrams of AVCAL Inventory Group Physical Structure and Record-Keeping Structure

carrier, and the number of line items within these inventory groups are normally established well in advance of a ship's deployment. Although each ship provides inputs to the process which determines the actual items included in the AVCAL and CLAMP listings, the final decisions rest with the Aviation Supply Office (ASO), Naval Air Systems Command (NAVAIRSYSCOM), and the appropriate Type Commander (COMNAVAIRPAC for Pacific Fleet Ships). Major changes to these listings occur only during ship overhauls or other extended periods when the ship is not deployed. POOL Listings are initially established by the process which creates the AVCAL listing; however, the number of POOL items is more flexible to adjustments. The number of POOL items may often be increased or decreased at the discretion of the ship's Supply Department <u>during</u> the actual deployment. The number of line items for the AVCAL, CLAMP, and POOL inventory groups are identified in this report by the variables AVLI, CLLI, and POLI, respectively.

2. <u>Range</u>

When an aircraft carrier deploys, it normally has 100 percent of its authorized inventory on board and in RFI condition. As the ship's deployment progresses, consumable parts are used and reordered, and repairable parts are broken and repaired. This rotation of inventory causes deficiencies in the ship's complement of RFI parts. These deficiencies in the inventory groups are measured by the Range variable, R:

$$R = \frac{\text{NALI RFI}}{\text{NALI}} \qquad (3)$$

where NALI RFI is the number of authorized line items in the inventory group with at least one RFI unit on hand, and NALI is the number of authorized line items in the inventory group. The AVCAL, CLAMP, and

POOL Range variables are identified in this report by the variables AR, CR, and PR, respectively.

3. Depth

The AVCAL, CLAMP, and POOL listings also establish limits on the quantity of each item that is carried in the inventory groups. These limits determine the authorized depth of stock for each line item. The depth of stock of an inventory group is affected by inventory rotations in a manner similar to the fluctuations experienced by the range of stock. The Depth variable X, however is not calculated by the same equation for all three inventory groups. CLAMP and POOL depth, CX and PX, respectively, are determined by the equation:

$$X = \frac{\text{NALI 100\% RFI}}{\text{NALI}} \qquad (4)$$

where NALI 100% RFI is the number of authorized line items in the inventory group that have 100 percent of their authorized quantity on hand and in RFI condition.

AVCAL depth, AX, is defined by the equation:

$$AX = \frac{\text{NALI RFI GE ROP}}{\text{NALI}} \qquad (5)$$

where NALI RFI GE ROP is the number of authorized line items in the AVCAL inventory with RFI units on hand greater than or equal to the reorder point. The reorder point is an inventory flag utilized by the SUADPS programs to signal replenishment action. A reorder point is established for each AVCAL inventory item, and it is computed primarily as the function of the on-hand balance of an item and the corresponding expected demand for the item during the lead-time period. Lead time is

the expected amount of time between placing an order for material and receiving it. When the on hand quantity of an AVCAL item decreases to the reorder point quantity (or below), replenishment material is ordered.

The Range and Depth variables can be categorized as indicators of the capability, or potential, that each inventory group has for satisfying demands for items of that group. The inventory effectiveness variables, discussed later in this section, are indicators of the performance level that each inventory group achieves in actually filling demands.

4. Demands and Issues

The number of demands each month for material from each of the inventory groups is recorded by the SUADPS programs, and these data are included as variables in the data base. The number of AVCAL, CLAMP, and POOL demands are identified in this report by the variables AD, CD, and PD, respectively.

Although the range of inventory items in the allowance lists is large, an aircraft carrier cannot carry every part which may be needed. Because of this, demands often occur for items that are not stocked. The demands for non-authorized items are included with the demands for authorized material to create the Demand data base. The distinction between types of demands is utilized in the next subsections covering inventory effectiveness.

If a demanded item happens to fall into more than one category, i.e., CLAMP/POOL or AVCAL/POOL, the demand is recorded for each applicable category. The quantity demanded for repairable items is always one unit, therefore, demands for CLAMP and POOL items will always be one unit per demand. The quantity for AVCAL consumables, however, is not necessarily

a single unit of issue. This distinction is not reflected by the Demand variables. By the same token, there are no distinctions made between partial issues and complete issues when a multiple quantity issue is made for a single demand.

5. Gross Effectiveness

Gross Effectiveness is one of two measures of effectiveness which document the ability to make issues for the demands placed on the AVCAL, CLAMP, and POOL inventories. Gross Effectiveness, G, is given by the equation:

$$G = \frac{\text{TOT ISS}}{\text{TOT DEM}} \tag{6}$$

where TOT ISS is the total number of issues made during a given month from on hand material in an inventory group, and TOT DEM is the total number of demands placed during the same month for material in the applicable inventory group. This includes demands for both authorized and non-authorized inventory items. Gross Effectiveness can be interpreted as a Fill Rate, and it measures the overall ability to satisfy any demand placed on one of the inventory groups.

6. Net Effectiveness

Net Effectiveness measures the ability to satisfy only the demand for authorized allowance list items. Net Effectiveness, N, is determined by the equation:

$$N = \frac{\text{TOT ISS}}{\text{TOT AUTH DEM}} \tag{7}$$

where TOT AUTH DEM is the number of demands placed during the month for authorized material in the applicable inventory group.

Since the numerical value of the denominator in the ratio defining Net Effectiveness will always be less than or equal to the numerical value of the denominator in the ratio of Gross Effectiveness, and the value of the numerators in both ratios are the same each month, Net Effectiveness will always be a number greater than or equal to Gross Effectiveness. The reason that there are two effectiveness ratios is related to the fact that the embarked squadrons are not usually given a complete listing of allowance material. When a squadron places a demand for a particular item, it may not be aware that the item is not carried on board the ship. This is normally the case for the AVCAL and CLAMP inventories. POOL items are an exception. The number of POOL line items is relatively small compared to that of AVCAL and CLAMP, and it is essential for squadrons to know which material is in the POOL inventory, so all squadrons are given a listing of POOL line items. By doing this, a squadron's requisition for a POOL item will always be for an item on the list; if not, it is rejected by the Supply Department before it is even counted as a demand. Thus, for POOL items, Gross Effectiveness always equals Net Effectiveness. This single value is called POOL Effectiveness and is represented in this report by the variable, PE. Gross Effectiveness for AVCAL and CLAMP inventories are represented by the variables AG and CG, respectively. Similarly, AN and CN represent the Net Effectiveness variables for the respective inventory groups.

7. POOL Zero Balance Rate

There is one final data base variable that belongs in this subsection, but it applies to only one of the inventory groups. This is the POOL Zero Balance Rate, and it is represented in this report by the

variable, PZBR. The PZBR is a measure of stock deficiencies in the POOL inventory. It is computed by the equation:

$$PZBR = \frac{\text{ZERO RFI}}{\text{NPLI}} \qquad (8)$$

where ZERO RFI is the number of line items in the POOL inventory with zero RFI material cn hand, and NPLI is the number of POOL inventory line items. The ZERO RFI data is obtained manually on board the ship by making a daily count of the POOL inventory items with no on-hand material in RFI condition. The daily PZBR values are averaged at the end of each month to provide the data base value.

The PZBR variable represents a redundancy in the reporting system, because it is a complementary variable of POOL Range. The only difference between the variables is that the Range variable reports an end-of-the-month value and PZBR reports the average value during a month.

## F. ACTION PENDING VARIABLES

This subsection introduces the variables in the data base which measure material backlogs that cause delays in the repair cycles of repairable inventory items. The data values of all the variables discussed here are manually collected by ship's personnel and represent end-of-the-month observations.

### 1. Factors Which Delay the Repair Process

When a non-RFI repairable item is inducted for repair by an aircraft carrier's maintenance activity, it often cannot be returned to an RFI condition within a short period of time, i.e., one to three days. This situation is normally caused by either of two factors. One factor

is that no immediate maintenance action can be performed on the item at the time it is inducted. This may happen because there are other similar items already in work, and the item joins a repair queue; or the diagnostic test bench necessary to repair the item is also broken; or the technician who works on the item may not be available at the time of the induction. When this occurs, the repairable component is placed in Awaiting Maintenance (AWM) status.

The second delay factor usually occurs after repair work has already been initiated on a component. A diagnostic check of the component may reveal that the item requires one or more repair parts, but they are not available from the ship's inventory or cannot be removed from a similar, non-RFI component (cannibalization). When this happens, the repair parts are ordered, and the non-RFI component is placed in a "holding" locker pending receipt of the material. Repairable components in this situation are placed in Awaiting Parts (AWP) status.

2. Definitions of Action Pending Variables

a. Components Awaiting Maintenance

This variable represents the total number of repairable components in AWM status on the last day of the month. It is labeled in the data base by the variable, AWMC.

b. Aged Components Awaiting Maintenance

This is the total number of repairable components in AWM status on the last day of a month that have been in that status for 15 or more days. It is labeled in the data base by the variable, AWM15. AWM15 is a subset of AWMC.

c. Components Awaiting Parts

This is the total number of repairable components in AWP status on the last day of the month. It is labeled AWPC in the data base.

d. Aged Components Awaiting Parts

This is the total number of repairable components in AWP status on the last day of a month that have been in that status for 30 or more days. It is labeled AWP30 in the data base and is a subset of AWPC. AWP30 also represents those components that were in AWP status at the end of the previous month but were not returned to RFI condition during the current month.

e. AWP Requisitions

This is the total number of requisitions for repair parts that are still outstanding on the last day of a month. It is labeled AWPR in the data base. AWPR data values document the total material requirements for the components in AWP status for the same month. AWPR is always greater than or equal to AWPC.

f. Aged AWP Requisitions

This is the total number of AWP requisitions outstanding on the last day of a month that have been on order for 60 or more days. It is labeled AWP60 in the data base and is a subset of AWPR.

## G. MAINTENANCE VARIABLES

This subsection introduces the four data base variables associated with the operation and performance of an aircraft carrier's aviation maintenance activity. One of these variables indicates the volume of non-RFI repairable equipment and components brought in for repair

each month. The remaining variables measure events which delay the repair processes or indicate the level of success achieved in returning non-RFI material to RFI condition. The data for these variables are collected manually by Maintenance personnel and are included in the twice-monthly AMR report.

1. Components Inducted

The total number of components inducted for repair each month provides an indication of the monthly workload of the maintenance activity. The information contained in this variable is similar to Demand data with respect to the manner in which it is recorded. Components inducted (COM) is simply the number of "induction events" which occur during a given month.

2. AWP Rate

The AWP rate measures the percentage of components inducted during a month which could not be immediately returned to RFI condition because the necessary repair parts were not available. The AWP rate, MP, is determined by the equation:

$$MP = \frac{COM\ AWP}{COM} \qquad (9)$$

where COM AWP is the number of inducted components which were in AWP status for more than three days during the month.

It may appear initially that the AWP rate is a redundant representation of the variables that report the number of components in AWP status (i.e., AWPC and AWP30), but it is not. The AWP rate should be viewed from the standpoint of the repair activity. It measures "problems" encountered by Maintenance personnel in their attempts to repair components.

Additionally, the AWP rate represents transactions which have already occured during the entire month. The AWPC and AWP30 variables, on the other hand, are end-of-the-month observations that represent "problems" for Supply personnel. These "problems" are still pending at the end of the month. It could be rationalized that a high AWP rate during a month would lead to a larger AWPC total at the end of the month. This is not necessarily the case, because components which enter AWP status during the repair process over a given month may consequently be repaired prior to the end of the same month.

3. AWM Rate

The AWM rate reports information that is similar in nature to the AWP-rate data. The AWM rate measures the percentage of components inducted during a month which could not be immediately returned to RFI condition because the necessary maintenance action could not be performed. The AWM rate, MM, is determined by the equation:

$$MM = \frac{COM\ AWM}{COM} \tag{10}$$

where COM AWM is the number of inducted components which were in AWM status for more than three days during the month.

The comparison of the AWM with the variable, AWMC, is analogous to the comparison of the AWP rate to the AWPC variable, with the exception that the AWMC variable, unlike the AWPC variable, represents a Maintenance "problem" that is still pending. Therefore, the AWM rate and the AWMC variable are measures of problems that are the responsibility of Maintenance to correct.

### 4. Repair Rate

The Repair rate measures the number of components returned to RFI condition by the repair activity during a given month. The Repair rate, MR, is determined by the equation:

$$MR = \frac{COM\ RFI}{COM} \qquad (11)$$

where COM RFI is the number of components repaired during the month.

When Code 40 Staff originally defined the Repair-rate variable, their intent was that it report the percentage of components inducted monthly that were subsequently repaired in the same month. However, the repair activities on board the aircraft carriers do not exclude prior months' inductions from their repair totals, and COM RFI is actually the total number of components repaired during a given month regardless of the month in which the components were originally inducted. The benefit of this variable for use in this study is questionable, since each observation is not truly representative of any single month.

## H. SUPPLY SYSTEM REQUISITIONS

When a consumable item causes a PMC or NMC condition on an aircraft, and when the demand cannot be issued from the ship's inventories due to the fact that it is Not In Stock (NIS) or Not Carried (NC), a requisition for the item is prepared by the ship's Supply Department in order to obtain the material from an off-ship source in the Supply System. Although there are usually stock requisitions for NIS material already outstanding in the Supply System, the PMC or NMC conditions warrant higher priorities in the ranking of requisition importance. Requisitions for items which are currently causing a PMC or NMC condition on an

aircraft are called PMCS and NMCS requisitions, respectively, and they are expedited more quickly than stock-replenishment requistions. The reason that a PMCS or NMCS requisition must document current aircraft discrepancies is because a stock requisition for the same item may still arrive before the higher-priority requisition, and the PMC/NMC discrepancy can be corrected from this receipt. When this occurs, the priority of the PMCS or NMCS requisition is downgraded to reflect the fact that it is no longer associated with an aircraft requirement.

Repairable-item-PMCS/NMCS demands which cannot be issued from the ship's inventories are requisitioned and expedited in the same way as consumables. However, the repair activity usually makes an attempt to repair the item before a requisition for a replacement component is prepared. There are several situations which may preclude repair. The repair activity may not be authorized to repair a particular item, or it is not capable of accomplishing the repair because of the unavailability of equipment, facilities, technical skills, technical data, or parts. An excessive backlog of items needing repair may also be considered. When any of these situations occur, a non-RFI component is classified as Beyond Capability of Maintenance (BCM), and a requisitioning process similar to the one for consumables goes into effect.

From the discussion in the preceding paragraphs, it is apparent that each PMCS or NMCS requisition is directly associated with a respective PMC or NMC aircraft. These aircraft, in turn, determine the aircraft readiness rates. The total number of PMCS and NMCS requisitions outstanding are reported each day by the AMR report. The daily PMCS/NMCS values are added together by the Code 40 Staff and are then averaged over

each month to create the data base variable represented in this report by P/NMCS.

It should be noted that the P/NMCS variable is the only variable in the data base that directly relates components and repair parts to PMC and NMC aircraft. The other variables that document various component status situations include PMCS/NMCS-related material, but the data is obscured by the inclusion of inventory-stock-related items.

I. ARTIFICIAL VARIABLES

The final variables of the data base are the two composite variables introduced in Section I as Support Factors. The reader will recall that the Support Factors are the weighted averages of several of the data base variables and were developed by the Code 40 Staff in an attempt to reduce the number of variables representing Supply Support Effectiveness. The Support Factors analyzed in this study are the Material Support Factor-Aviation and the Component Repair Factor.

1. Material Support Factor-Aviation (MSFA)

The MSFA variable combines inventory-related variables in order to provide an indication of the relative level of aviation material support achieved each month by a ship's Supply Department. Using the notation established previously for the data base variables, MSFA is determined by the equation:

$$MSFA = \frac{4(AN + AG + CN + PE) + AR + AX - CR + CX + PR + PX}{22} \quad (12)$$

Each of the input variables of the MSFA equation is a percentage ratio; therefore, the denominator value of 22 is used to keep the numerical value of MSFA between zero and one. It can be seen from equation (12)

that the inventory variables which measure actual inventory performance (i.e., inventory effectiveness) have been weighted more heavily than the variables which measure inventory potential (i.e., range and depth). This subjective weighting represents the Code 40 Staff's assessment of the relative importance of inventory effectiveness to the MSFA equation, and consequently, to management decisions.

2. Component Repair Factor (CRF)

The CRF variable combines the maintenance variables, MR, MP and MM with the POOL Zero Balance Rate (PZBR) to produce a composite indicator of Maintenance Support. The Component Repair Factor is determined by the equation:

$$CRF = \frac{3(1 - PZBR) + MR - MP - 2MM}{4} . \qquad (13)$$

The quantity, (1 - PZBR), represents the value of the POOL Range, PR, averaged over the applicable month. Although the POOL-related variables will be shown later in this report to be significant performance indicators, no logical explanation as to why the POOL variable was included in the CRF equation was offered by the Code 40 Staff. The negative weights assigned to the variables MP and MM are indicative of the intuitive assumptions that the respective AWP and AWM events that occur during monthly repair actions detract in some way from overall Maintenance performance. The denominator value of 4 is used to keep the numerical value of CRF between zero and one, and it is based on the respective coefficients (3 and 1) of the quantities (1 - PZBR), and MR.

## J. DATA EXCLUDED FROM ANALYSES

An initial step performed in the analyses of this study consisted of a preliminary culling of the available data and the consideration of additional or alternative sources of data that could improve, purify, or simplify the data base. This section discusses the variables or observations which have not been incorporated into this study.

### 1. Atlantic Fleet Aircraft Carriers

The supply performance data base that is analyzed in this study contains only the observations from Pacific Fleet ships under the cognizance of COMNAVAIRPAC. The inclusion of similar data observations from Atlantic Fleet aircraft carriers was considered for use in the analyses; however, the author decided to exclude these data. This decision was based on the fact that the Atlantic Fleet ships are not directed by the supply and maintenance philosophies mandated by COMNAVAIRPAC; it was further based on the assumption that, in addition to other intangibles, the different replenishment-material pipeline extending to ships deployed in the Atlantic and Mediterranean Oceans would create additional variance or noise in the analyses.

### 2. Other Ships With Embarked Aircraft

The complete logistic-support data base of COMNAVAIRPAC includes aviation and non-aviation supply performance data for Pacific Fleet aircraft carriers (CV), amphibious assault (LPH) ships, and general purpose assault (LHA) ships. Because the objectives of this study are centered around the performance of aircraft carriers, the observations from LPH and LHA ships have been omitted in order to maintain a data base as homogeneous as possible. The LPH/LHA data, though similar in content

to the CV data, are not actually comparable for the purposes of this study. The operational missions of both the LPH and LHA ships are quite different than those of aircraft carriers. Although all these vessels carry embarked aircraft, LPH and LHA ships do not have the large number and many types of aircraft that are characteristic of aircraft carriers. As a consequence, LPH and LHA ships have AVCAL, CLAMP, and POOL inventories that are considerably different in both range and depth than the respective inventories authorized for aircraft carriers. At the time this study was conducted, a sufficient number of observations from LPH/LHA ships had not yet been established in the data base; individual analyses of these ships were not feasible.

3. Non-Aviation Supply Performance Data

Variables in the automated Code 40 data base that report non-aviation supply-performance statistics have also been excluded from this study. These variables measure the Range, Depth, Gross Effectiveness, and Number of Line Items for the Coordinated Shipboard Allowance List (COSAL) inventory group. The reader will recall that only two of the three artificial variables created by the Code 40 Staff have been included in this report. The third Support Factor is the weighted average of the Range, Depth, and Effectiveness variables for the COSAL inventory; it also has been excluded from the analyses. Although it is true that the COSAL variables constitute a portion of the overall supply-support-effectiveness concept, there is no compelling reason to support their inclusion in any analyses of aircraft readiness and aviation supply performance.

4. Variables With Incomplete Data

There is one variable in the automated data base which has been excluded due to missing observations. This variable measures the number of repairable components in AWM status at the end of a month that have been in that status for 15 days or more. The observations for this variable could not be obtained from the aircraft carrier, CV5, and since the 11 observations from CV5 compose over one third of the total observations, the variable was omitted.

K. SUMMARY OF DATA-BASE VARIABLES

Many of the variables presented in this section will be discussed and analyzed in detail in Section IV. In most cases, the variables will be referred to by the symbols or acronyms used in the definitions developed in this section. The reader should refer to the List of Symbols, Acronyms, and Abbreviations which precedes the Introduction to this report in order to reference the nomenclature or description of each variable.

# III. ANALYTICAL PROCEDURE

An often encountered dilemma in any analyses of data has typically been the question of what to do with the data at hand. There exists a multitude of data analysis techniques and theories available for use; and as Hensley states, "Although one might hope for some optimal methodology for the analysis and appraisal of a given system, it is usually the case that peculiarities in development or functional attributes preclude strict adherence to a unique analytical procedure." [Ref. 7] Many useful techniques are limited by the amount of data or the nature of the data that is available. Theoretical assumptions on the data and corresponding restrictions imposed by analytical models may also limit the analysis process, perhaps in a manner unknown to the analyst. In this section, the analytical methods employed by this study are presented, and a brief description of each technique is provided in order to help the reader gain some insights into the problems inherent in, or revealed by the data.

## A. GRAPHIC ANALYSIS

Analysis of data using simple graphs and plots of data observations is probably one of the oldest analytical techniques in existence; yet, it continues to be a useful tool for examining the relationships between variables, or suggesting the absence of a strong, useful relationship. A critical assumption of the methods discussed later in this section is that the variables in any particular model must have a linear relationship, at least approximately. The linearity of the relation between two

variables may be easily checked by plotting one versus the other. A visual look at the data can help identify irregularities or inconsistencies and may also suggest data transformations which can correct a nonlinear relationship.

In this study, scatter plots of variables have been utilized for analysis, and were obtained by the graphic-generating features of the Interactive Data Analysis (IDA) statistical computer package, which is discussed at the end of this section. A peculiarity of the scatter plots generated by IDA is that the data is standardized prior to plotting. Standardizing the data involves computing the mean and standard deviation according to the number of observations and then modifying the data by subtracting the mean from each ovservation and dividing each result by the standard deviation. Although this procedure "masks" the true numeric value of each observation, no statisitical information is lost in the transformation. The original values may be retrieved by reversing the steps of the standardizing procedure.

As a final point of interest here, the reader should note that the means and standard deviations of the MC and FMC variables have been omitted from this report for security reasons, and only the standardized values are reported. Therefore, all scatter plots involving these variables will indicate their means and standard deviations as 0 and 1, respectively.

## B. CORRELATION ANALYSIS

Correlation analysis quantitatively examines the linear relationship between the variables in a data set. This technique is quite useful because it quantifies the association between variables without assuming

a model or any cause-and-effect relationship. In general, two variables are said to be correlated when it can be seen that an increase in the value of one variable is accompanied by a simultaneous increase or decrease in the value of the other variable.

Correlation analysis provides the analyst with a single summary statistic describing the strength of the association between two variables. This statistic, known as the correlation coefficient, measures the interdependence of two random variables over a scale that ranges from -1 to +1. A value of +1 indicates a perfect positive linear relationship while a value of -1 indicates a perfect negative linear relationship. A value of zero indicates no linear relationship at all. However, this does not preclude the fact that a perfect nonlinear relationship may exist.

In this study, the examination of the correlation coefficients is used extensively to develop hypotheses concerning the relationships among variables.

## C. REGRESSION ANALYSIS

### 1. Description and Purposes

Regression analysis is a widely used (and abused) statistical tool for determining the relationships between two or more quantitative variables. There are basically three distinct activities, or purposes, of regression. The first of these is structural analysis which, simply stated, amounts to fitting a linear "curve" to the available data. This provides a summary display which can be utilized for descriptive purposes, and it gives the analyst an idea of what the data is doing, i.e., it describes the relationship between the variables. The variable that one wishes to explain is known as the dependent or response varible. Variables

that are used in the attempt to describe the dependent variable are called independent or explanatory variables. It will be seen later that mutual dependence of explanatory variables is hard to avoid in this study, and others. Regression models that use one variable to explain another are called single-variable regressions. Analysis using regressions involving two or more independent variables is known as multivariate regression analysis and is one of the methods used by this study.

The second use of regression is in the field of forecasting, or prediction. By using an assumed system or model, one can predict future responses to stimuli, and assess the degree of certainty with which the prediction is made. Forecasting by regression is restricted by many assumptions and considerations that must be applied to both the data and the model. As pointed out earlier, the data available for this study do not report enough information outside the control of Supply, nor are the data provided in sufficient quantity, to enable construction of a model to well-predict aircraft readiness. No evaluation of predictability using regression has been attempted here.

The third purpose of regression is to gain insights on what is actually occurring in the relationship between the variables. This involves the use of diagnostic checks or tests for the statistical significance of any assumed model and the evaluation of how accurately these assumptions and estimates provide a useful description of the "real world."

2. Applications, Assumptions, and Caveats

The primary use of regression analysis in this study will be for descriptive purposes. Some consideration is given to statistical

tests of the significance of the models derived. The major problem with the use of regression analysis for model building is that there are infinitely many models available. Prior knowledge of the nature of the variables may help the analyst to omit certain models from consideration, but the task is still large. Moreover, regression analysis assumes that there is a permanent, useful, relationship between the response and explanatory variables. It does not attempt to prove this. The analyst can easily "paint himself into a corner" during the process of empirical model building, because if he lets the data "speak for itself" to suggest relationships or transformations, he cannot confirm his results using the same data. A large part of the work that went into this study attempted to find the "best" model and apply the data to it. An even greater part of the study was the negative results that were obtained from model after model after model.

The use of regression analysis is limited by many underlying assumptions which provide the basis for the theory behind regression techniques. In this study, the assumption is made that the relationships between the variables is approximately linear. This provides a starting point for justifying the use of regression models. The statistical statements and tests utilized herein require other assumptions which may or may not be valid and, unfortunately, cannot be validated in all cases because the data available is limited.

The regression models examined in this study are based on a technique known as least-squares regression.[3] In addition to the

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[3]An explanation of the least-squares method can be found in any of the texts cited in the Bibliography.

linearity assumption invoked for this technique, the usual inferential techniques of regression analysis assume: (1) that the error terms, or deviations, are not independent of each other; (2) that these errors have a Normal distribution; and (3) that the variance of these error terms is constant. Although the assumption of constant variance is critical to forecasting and structural modeling, least-squares fitting can be justified without such strong assumptions.

3. Normality

As mentioned previously, the small number of available observations precludes many desirable tests. One of these is a test to see if the observations are distributed normally. The statistical tests used in this study are fairly robust without the strict assumption of normality; therefore, only a simple check of the observations by normal probability plots is utilized. If the data have a normal distribution, they will plot in a reasonably straight line along the 45 degree diagonal of a normal probability graph. This method avoids the issue of normality somewhat because there do exist several statistical tests for normality. In the interest of simplicity, the author opted for the method described.

4. Statistical Tests and Measures of the Goodness-of-Fit

The regression process takes the observed data of the variables included in the assumed model and applies it to the statistical mechanics developed by theory in order to fit a linear equation to the observations. The end result is a set of estimated coefficients for the variables in the model. These coefficients are commonly referred to as Best-Linear-Unbiased-Estimators (BLUE). Naturally, one would like to know if the regression equation does a good job of explaining the data. The tests

that follow provide indications of the goodness-of-fit and are used in this study.

a. Analysis of Variance (ANOVA)

With all the methods available to develop models which estimate the numeric value of a variable, the simplest technique is to just calculate the average value of the observations for each variable and use these mean values as estimates. This is called the "null model." If the data take a wide range of values, the null model does not offer a very good estimate of the real world, since many of the observations will deviate from the mean value. A regression model attempts to minimize these deviations by fitting a linear relationship (equation) to the data.

ANOVA tables measure the goodness-of-fit of a regression model against the null model by examining the deviations of the observed data from the null model and comparing them with the data deviations due to the regression model. The summary test statistic used to evaluate how well the model fits the data is known as the F-Statistic. If the value of the F-statistic is large, the model is a good fit. If the F-value is small, the fit is poor, and an F-value of zero indicates no fit at all; i.e., the null model provides an adequate estimate, as compared to the more complex model. The F-statistic tests the hypothesis that the values of all the coefficients of the regression model variables cannot be statistically differentiated from zero. This is contrasted to the hypothesis that at lease one of the coefficients in the model is statistically different from zero. In other words, it tests whether or not the regression model is significantly better than the null model. The F-test

and the ANOVA technique require that the assumptions of normality and constant variance discussed previously be fulfilled, at least approximately.

b. The t-Test Statistic

The t-statistic can be used to check for the statistical significance of individual variables in the regression model. The derivation of the t-test is based on the same theory behind the F-statistic, and the difference between the two tests is that the t-test is applied to the individual variables in the model while the F-test looks at all the variables simultaneously. The decision of whether or not an individual variable has a coefficient that is significantly distinguishable from zero is based on the magnitude of the t-statistic value. Like the F-test, high values of the t-statistic indicate statistically significant influence by the variable in question. A small t-value (near zero) indicates that a variable has nothing to offer to the model, i.e., has negligible explanatory power. Unlike the F-statistic, the t-statistic takes on negative values if the sign of the coefficient is negative. Moreover, the relative "strength" of each variable with respect to how much it appears to contribute to the explanation of variance in the model can be determined by comparing the absolute values of the t-statistic for each variable. This feature is used in some of the regression techniques discussed later.

c. Coefficient of Multiple Determination

The coefficient of multiple determination, also known as R-squared, measures the proportion of total variation accounted for or explained by the regression model. An R-squared value of 1 implies a perfect fit of the model, while a value of 0 implies no fit. R-squared

is not the best indicator of the fit of a model because the magnitude of error in relation to the goodness-of-fit depends on what is being measured. When the observations of data are taken at only a few levels for each variable, as is the case in this study, a large R-square value does not necessarily imply that the fitted regression model is a useful one. In view of this, this study does not attach a great deal of significance to the values of R-squared obtained.

5. Problems Encountered

Some of the problems encountered with the use of regression models are centered around the failure of the data to conform to the assumptions of normality and constant variance. A major shortcoming of the data in this study is the absence of independence among the independent or explanatory variables. Ideally, one would like to have a set of explanatory variables which describe the dependent variable without interdependencies among themselves. When this is not the case and the variables exhibit a particularly high amount of correlation between each other, the condition known as multicolinearity exists.

One of the consequences of multicolinearity is that it becomes difficult to obtain precise estimates of the separate effects of the independent variables. Although one may obtain information on the model as a whole, individual inferences cannot be made on the variables that compose it. In other words, several of the variables in a model may be non-significant (i.e., low t-statistic values), but the overall significance of the model (as measured by the F-statistic) may be quite high. This can make the assessment of a particular model's "worthiness" very difficult.

6. Stepwise Regression

When one is faced with a large number of variables such as the set that is employed in this study, the natural inclination is to try to reduce the number to a workable subset. An additional motivation toward this goal is the fact that a model with a large number of variables can be expensive to maintain, and a parsimonious reduction of variables (as applied to this study) may serve to relieve the reporting ships of some of the burden caused by data collection.

One way in which to find the "best" set of variables for a model would be to look at all possible combinations of the variables in regression models. This is known as the "all possible regressions" method. It is easy to see, however, that the large number of variables in this study prohibits an analysis of this type. An alternative to this approach is stepwise regression which economizes on the computational effort involved in the search for a "best" set of explanatory variables. Stepwise regression computes a sequence of regression equations, and adds or deletes a variable at each iteration depending on the desired direction of the search. In simple terms, the criterion for adding or deleting a variable in a regression equation is based on how much each candidate variable has to offer the model in terms of "explanatory power," or it is based on which variable already in the model contributes the least to the equation. The criterion that is utilized depends on whether one is adding, or deleting, variables, and the respective processes that accomplish this are known as forward regression and backward regression.

Both forward and backward regression techniques are used in this study. It should be noted that there are limitations to these methods,

since they presume that a "best" set of variables actually exists. These types of procedures are typical of analyses that "let the data speak." The problem with this is that quite often the data have very little to say, or what they do say does not make any sense or agree with intuitive knowledge. This is particularly true when the explanatory data are highly correlated or colinear.

## D. OTHER ANALYTICAL CONSIDERATIONS NOT INCLUDED

### 1. Time-Series Analysis

When the deviations or error terms in a regression model are correlated over time, they are said to be autocorrelated. This often occurs in a study of time-series data. Time-series data consists of observations of variables collected during successive time periods. The monthly observations of the supply performance variables in this study could easily be placed in this category, but the small number of observations on the variables requires pooling the data into a cross-sectional sample. This complicates the issue because time-series and cross-section data usually generate different estimates for the coefficients of the variables in a model. An additional problem encountered in this particular study is that not all of the data collected for the study variables represent sequential observations. The reader may recall that the data base was established from observations over a consecutive 13 month period. Within this collection "window," observations of ships started and stopped at various stages of their deployment cycles. Because of this, the effects of time on the variables over the entire deployment of an aircraft carrier could not be examined, and time-series analyses were

not attempted in this study. Additional discussion of the time-series effect is presented in the recommendations section of this report.

2. Principal Component Analysis

Principal component analysis is a technique that reduces the number of explanatory variables in a model by reorienting the dimensional structure of the data according to the amount of variability exhibited by each variable. In a two-dimensional representation such as a scatter plot, this reorienting simply amounts to rotating the x and y axes so that the x-axis, or "first principal component" follows along the direction where the data is spread out to the greatest extent. The second principal component is oriented perpendicular to the first, and it follows the direction of the second greatest variability. In general, this process continues until all the available axes have been reoriented or until further reorientation does not improve the model. The end result is that the data "fit" around the newly dimensioned basis more tightly, and these data can often be expressed more efficiently in terms of this new basis. Those variables that do not contribute significantly to the new orientation can usually be removed from the model without much loss in its explanatory power, thus reducing the total number of variables to be studied.

Analysis by principal components is not easily accomplished without the use of a statistical software package that is accessable through a mainframe computer system. Deadlines combined with the author's unfamiliarity with the available software prevented an in-depth analysis of this type, and only a few "test runs" using this method on the data

were attempted. The results warrant further investigation but are not included in this report.

## E. EQUIPMENT UTILIZED

The analyses conducted on the data base of this study were accomplished using the IDA Interactive Data Analysis and Forecasting System. IDA is one of several good statistical software packages currently available to analysts, and the reader who desires to know more about this system is encouraged to consult the IDA's user's guide listed in the Bibliography.

The statistical computations of this study were executed by the IBM 3033 Virtual Machine System located at the Naval Postgraduate School, Monterey.

## IV. RESULTS AND INTERPRETATIONS

In the previous section, the basic analytical tools and statistical assumptions were presented in order to lay the foundation for a systematic and logical approach to the analyses of the data base. In the present section, these tools are used to examine the relationships between the Code 40 Support Factors and the performance variables and also some of the interrelationships within the data base. The results which follow are a representative sample of several hundred different analyses which were performed during the study, and by no means do they represent a final solution to the problem. What follows is: (1) an assessment of the Code 40 Support Factors as evidenced by the available data; (2) an alternative approach to the problem; and (3) several analyses which look at some of the more noteworthy interrelationships. These results are preceded by a discussion of the nature of the data and also a discussion of some preliminary investigations and insights which led to an initial culling of several observations and variables.

### A. THE NATURE OF THE DATA

The reader may recall from Sections I and II that each collection of performance variable observations is stored as a monthly data set in the automated Code 40 data base. These data are monthly in the sense that a single numeric value is used to report a performance or potential-for-performance statistic that is purported to be representative of the applicable month. These data are collected from two different source reports over different time intervals. Because of this and the fact

that the methods of data collection are subject to the type of data as well as the perspective from which the data are measured, many of the variables in the data base are not truly comprehensive over an entire month. As a followup to the discussions in Section II which explained what each variable reports, this subsection discusses how they are reported and examines why the particular reporting methodologies may complicate interpretation of analyses results.

1. Frequency of Reports

In Section II, it was seen that the AMR report is received daily by the Code 40 Staff. As each report is received, the values of the MC, FMC, and P/NMCS variables are retrieved and are manually recorded on a daily record sheet. At the end of the month, each set of values for these variables is averaged, and these averages are entered into the data base. The monthly value for each of these variables then, is just the average daily value of the performance variable during the applicable month. This method of data-base-value computation is made possible only by the fact that the data is available to Code 40 on a daily basis. It will be seen later that most of the data-base values of the variables are not computed this way.

All other variables included in this study, with the exception of the Support Factor variables, are collected from the ASR report. The reporting methodologies for these variables are relatively straightforward; however, there is one peculiarity of the ASR report that requires explanation. Many of the values of data reported by the ASR report are totals or averages computed mechanically by SUADPS programming. The reader will recall that these values are sent to COMNAVAIRPAC via the ASR report

twice a month. The first report covers the first 15 days of the month and contains variable totals and averages that have been collected and computed to that point in time. The second report is submitted within five days after the end of the report month, and it contains the performance data, averages, and totals over the entire month, incorporating the data from the first report into the second report's values. Because of the nature of this reporting method, only the end-of-the-month ASR report is used by the Code 40 Staff for input to the automated data base.

2. Average Daily Values and Monthly Rates

In the preceding subsection, it was seen that the variable, P/NMCS, represents the average daily number of total PMCS and NMCS requisitions outstanding that are reported by deployed ships. Similarly, the MC and FMC variables reflect average daily ratios of respective MC and FMC aircraft to total aircraft. Only one other variable in the data base is averaged in a similar manner. This variable is the Pool Zero Balance Rate (PZBR) which represents the average ratio of POOL line items with no RFI material on hand to the total number of POOL line items. The only difference in the averaging methods is that the PZBR data are collected manually and averaged by ship's personnel prior to transmitting the twice-monthly ASR report, while the averages for the MC, FMC, and P/NMCS variables are computed manually by the Code 40 Staff after they have collected a month's worth of data from the daily AMR reports.

The MC, FMC, and PZBR variables are three of the eleven variables in the data base which report various ratios, or rates. These three variables, however, are the only ones that represent average daily rates. The remaining eight variables in this group represent monthly rates.

The rationale for this apparent disparity of reporting methodologies can be seen when one takes a closer look at the nature of the data that is being reported. The monthly rate variables, identified later in this section, are measures of the discrete-but-recurring events that document various Supply and Maintenance transactions which occur during a given month. For example, the inventory effectiveness rates (Gross and Net Effectiveness) are determined by counting the number of issues made from stock in an inventory group during a month and dividing this sum by the total number of demands for items in the same group during the same month. Each demand and each corresponding issue or non-issue are individually recorded as event occurences. Once a demand is placed, or an issue is made, it is registered as an occurence, and the procedure moves on to the next event. The MC, FMC, and PZBR variables, on the other hand, measure events that are of a continuing nature. An individual aircraft that is reported to be in MC or NMC status one day may also be in the same status the next day, or the day after that, and so on. Similarly, a line item in the Rotatable Pool may be not-in-stock for many consecutive days, or a zero balance for an item may occur during several intermittent periods during a month.

It can be seen from the preceding discussion that the numerous "rate" variables in the data base can be separated into two distinct groups, based on two totally different data collection concepts. How these concepts affect the interaction between the variables in each category and other variables in the data base is not clear; however, the method of recording inventory event occurences lends itself to some

comments and suggestions for analysis by queueing theory. These are presented in the final section of this report.

It should be noted here that the P/NMCS variable, as well as some of the other variables that will be examined, also report events, or "problems" that are of a continuing nature. In other words, the variables report events which have occured but are yet-to-be resolved. This situation is characteristic of the PMCS and NMCS requisitioning process. The "event" of establishing a requisition is initially recorded at the point in time when it is determined that the requirement cannot be filled from an on-ship source, but the "event" of receiving the requisitioned material may not occur for several days, weeks, or months in the future. Once again, this type of process suggests areas for additional analyses and is addressed in the recommendations section of this report.

3. End-of-the-Month Observations

In subsection IV.A.1 of this section, it was seen that the source document for the majority (27 of 33) of the variables in the data base is the end-of-the-month (EOM) ASR report. The 18 remaining variables from the ASR report carry data that represent EOM-type observations. These variables can be divided into two groups: EOM-Summary variables and EOM-Snapshot variables.

a. Summary Observations

The EOM-Summary variables are the data-base variables which report the total number of demands during a month for items in each of the three inventory groups, i.e., AVCAL Demands (AD), CLAMP Demands (CD), and POOL Demands (PD). The total number of components inducted (COM) may also be categorized as an EOM-SUMMARY variable. These variables

are simply the monthly counts of the number of event occurences within each applicable category (i.e., Demands or Inductions).

The information carried by these variables is structured on a scale that is totally different from the scale for the rate variables. Since the rate variables are ratios, their values will always be confined to the range from 0 to 1. The EOM-Summary variables will always be integer values and can theoretically range from 0 to infinity. Despite this disparity, the EOM-Summary variables are still useful performance indicators and present no immediate problems for use with rate variables in regression models. This is because both types of variables carry a "month's worth" of data. It will be seen that the next observation-type does not accomplish this and may create problems in both the development of regression models and their interpretation.

b. Snapshot Observations

EOM-Snapshot variables are exactly what the label implies. A single "snapshot" observation is taken on the last day of the month for each of the applicable performance indicators, and these values are included in the data base as the measures of performance for the month in question. It is easy to see from this that an EOM-Snapshot variable is not truly representative of performance over an entire month. Variables that report EOM-Snapshot data include the Range, Depth, and Number-of-Line-Items variables for each of the three inventory groups. Also included in this category are the variables that carry the data for the repairable components that are in AWP or AWM status.

A first impression taken by the author in regard to the usefulness of these variables was that an EOM-Snapshot variable might be

of value to a manager, because the information it carries is much more "current" than data that are generated over a month's time. This is particularly true of the EOM-Snapshot variables which reflect AWP and AWM data. An excessively large number of components reported to be in AWP or AWM status on the last day of the month could trigger a response to assist the ship much faster than it could be accomplished if the data were allowed to "collect" over the month (or half-month). An assist could come in the form of additional parts or personnel or simply the authorization for the ship to initiate BCM action on the backlogged material.

A rationale for using the EOM-Snapshot observations for Range and Depth potential-for-performance indicators, instead of using a summary or average value, was provided by the Code 40 Staff. It was explained that the levels of Range and Depth for each of the inventory groups were characteristically slow to change value because of the large number of line items in each group; thus, an EOM observation could be used as an approximation to the average daily value without much loss of accuracy.

The logic behind this explanation initially appears to be sound; however, if one examines the data base, it becomes apparent that the assumptions made on the inventory groups are not supported by the data. Only the AVCAL inventory group has what could be considered a large number of line items. Using the values listed in Table 9 in Appendix B, the average number of line items in the AVCAL inventory is over 19 times greater than the average number of line items in the Rotatable Pool. Even so, the raw data (tabled in Appendix C) indicates

that the numbers of line items in the ships' AVCAL's are continually changing. For example, the number of AVCAL line items reported by aircraft carrier CV5 at the end of one month was 35,605 items. By the end of the next month, this value was reported to be 40,274 items, an increase of over 13 percent from the previous month.

It is granted that inventory changes of this magnitude are unusual, but a closer look at the actual values for the Range and Depth variables of all three inventory groups indicate that these variables are actually not so slow to change in value from month to month. Increases or decreases by as much as five percent from one month to the next are not uncommon.

It is interesting to note here that the CLAMP Range and Depth values vary much less from month to month than either of the corresponding AVCAL or POOL values. This may indicate that the intensified management procedures for the high-visibility CLAMP items are effective. On the other hand, the CLAMP Range and Depth values may look better than the AVCAL figures simply because of the fact that all CLAMP items are repairable, and inventory stock can usually be replenished by local repair. Since the AVCAL inventory contains many consumable line items which must be replenished from off-ship sources, the AVCAL Range and Depth may be subject to greater fluctuations as a function of the requisition-lead-time delay experienced when consumable replenishment stock is reordered.

The Range and Depth values for the Rotatable Pool may also appear to have greater variation than both the CLAMP and AVCAL values because of the higher demand for POOL inventory items. Although the

items in the POOL inventory consist entirely of repairables from either the AVCAL or CLAMP inventories, the additional "distinction" of being a POOL item is made because of the fact that they are demanded more frequently. This means that even though the POOL inventory can be replenished by local repair, just as the CLAMP inventory is replenished, it is more likely that a greater percentage of POOL line items will be out of RFI stock simply because they are used more often.

This is the key point of this discussion; it relates to a basic problem with using EOM-Snapshot variables as performance indicators. Since all inventory items experience random demand, the use of an EOM-Snapshot variabale to describe monthly performance may artificially inflate or deflate the true measure of performance from month to month. In the case of POOL inventory items, which experience frequent random demand, this could occur from day to day, particularly since the number of POOL line items is comparatively small compared to that of the AVCAL and CLAMP inventories.

The dilemma presented in the previous discussion is quite obvious and may develop serious ramifications to the present study. Since the EOM-Snapshot variables are singular in nature, while the remaining variables of the data base are collective in nature, the inclusion of both types of variables in regression models may amount to the situation of "comparing apples to oranges;" i.e., they may not be compatible for the purposes of this study. On the other hand, if a cause-and-effect relationship is assumed, one might argue that a particular EOM-value could be attributed to the effect of one or more performance factors at work during the entire month. For example, a large number of

components in AWM status at the end of a month might be the result of a high AWM rate that was measured for that month. Conversely, one might argue than an EOM-value, which is also the value that represents the beginning of the next month, could influence the value of several summary or averaged-type variables observed in that subsequent month.

The dichotomy of directions in which to take the analyses from here is straightforward: either omit the EOM-Snapshot variables or include them in the problem. Because this field of study is relatively new, and because the present research is interested in the descriptive powers of the variables, the author decided to include the variables in the study.

### 4. Summary of Data-Types

Table 2 lists the report symbol for each of the data base variables and identifies both the data source (AMR Report, ASR Report, or Code 40 Staff) and the type of observation (Average Daily Value or Rate, Monthly Rate, EOM-Summary, or EOM-Snapshot) that is reported by each variable. The reader should refer to the List of Symbols, Acronyms, and Abbreviations that precedes Section I for a brief description of the nomenclature of each report symbol.

## B. PRELIMINARY INVESTIGATIONS

As a prelude to the analyses of the Support Factors and the study of interrelationships between variables, several preliminary investigations were conducted in order to assess the appropriateness of using all of the available data in the study. It was also desired to test the assumption of normality of the data so that the goodness-of-fit tests could be used from a proper perspective. These investigations are

TABLE 2

DATA TYPES AND SOURCES

| Variable | Data Type | Data Source |
|---|---|---|
| AR | EOM Summary | ASR |
| AG | Monthly Rate | ASR |
| AN | Monthly Rate | ASR |
| AR | EOM Snapshot | ASR |
| AVLI | EOM Snapshot | ASR |
| AX | EOM Snapshot | ASR |
| AWMC | EOM Snapshot | ASR |
| AWPC | EOM Snapshot | ASR |
| AWPR | EOM Snapshot | ASR |
| AWP30 | EOM Snapshot | ASR |
| AWP60 | EOM Snapshot | ASR |
| CD | EOM Summary | ASR |
| CG | Monthly Rate | ASR |
| CLLI | EOM Snapshot | ASR |
| CN | Monthly Rate | ASR |
| COM | EOM Summary | ASR |
| CR | EOM Snapshot | ASR |
| CRF | Artificial | Code 40 |
| CX | EOM Snapshot | ASR |
| FMC | Avg Daily Rate | AMR |
| MC | Avg Daily Rate | AMR |
| MM | Monthly Rate | ASR |
| MP | Monthly Rate | ASR |
| MR | Monthly Rate | ASR |
| MSFA | Artificial | Code 40 |
| PD | EOM Summary | ASR |
| PE | Monthly Rate | ASR |
| POLI | EOM Snapshot | ASR |
| PR | EOM Snapshot | ASR |
| PX | EOM Snapshot | ASR |
| PZBR | Avg Daily Rate | ASR |
| P/NMCS | Avg Daily Rate | AMR |

presented here and conclude with a brief explanation and sample of the scatter plots and tables utilized in the various analyses of the data.

1. Assessment of the Data Sources

One of the first questions that arises in any analysis of data is whether or not all of the available observations and variables are appropriate for use in the study. The selection of the study variables has been previously addressed, but the question of which observations to include remains to be answered. This is particularly important to the present study, since the observations come from five different ship sources. If one or more of these sources is dissimilar, this could bias or invalidate the data, and the subsequent analyses would be inappropriate.

When the data for this study was first received from COMNAVAIRPAC, the Code 40 Staff pointed out that aircraft carrier CV4 had experienced a less-than-satisfactory deployment (from the standpoint of Supply Support). This led the author to believe that perhaps this ship had experienced one or more intangible-related events which might have brought about the poor performance. The Code 40 Staff indicated that this was not the case. A subsequent comparison of the mean values of the CV4 data with the mean values[4] of the other ships revealed a trend that was both interesting and encouraging. The mean values of the MC and FMC variables were naturally lower than the corresponding means of the other ships, but the mean values of the Supply and Maintenance performance variables were *also* correspondingly above or below the means of other ships. This was encouraging, because it agreed with the intuitive directions of

[4]The mean values of the variables for each ship are tabulated in Appendix A.

influence that the performance variables were expected to take. For example, one could expect a high availability of parts (as measured by the Range and Depth variables) to be associated with higher values of aircraft readiness. Similarly, a large number of components in AWP or AWM status should correspond with lower values of readiness. These types of intuitive arguments were characterized exactly by the CV4 data, therefore, these data were included in the study.

The mean values of the variables from the remaining ships could not be compared as easily as the CV4 means, because the mean values from the other ships were more closely grouped together for the majority of the variables in this study. In order to alleviate this problem, a correlation matrix of the variables was generated for each ship. Each matrix is based on only the data from the ship in question. In addition to these matrices, a correlation matrix was generated using all available data. These matrices are listed in Appendix B.

As explained earlier, the correlation matrix provides an indication of the association between variables as evidenced by the data. For the purpose of assessing the data from each ship, the major concern here was not how strongly associated any two variables might be; instead, the positive or negative association between the variables was examined. In particular, the MC, FMC, and P/NMCS variables were selected, and the correlation coefficients between these variables and the remaining variables of the study were examined. The MC and FMC variables were used because their intuitive positive or negative associations with the performance variables were relatively obvious to the author. The P/NMCS

variable was also selected for similar reasons, but also because this variable plays a key role in the analysis, as will be seen later.

In a procedure similar to the comparison of the mean values, the signs of the correlation coefficients were examined for each ship. These signs were then compared with the signs on the coefficients generated by using all observations and also compared with the intuitive signs of the correlations. The individual results are not presented here but will be briefly summarized.

With the exception of five variables, all of the correlation signs agreed with the positive or negative intuitive signs when all observations were utilized to generate the correlation matrix.[5] A closer look at the correlation matrices of the individual ships revealed that the data from aircraft carriers CV2 and CV3 did not behave as expected, particularly when compared to the other three ships. These findings were presented to the Code 40 Staff, and it was discovered that aircraft carrier CV2 had incorporated a new version of the SUADPS programs which maintained the ship's records and files. This revision had not been accomplished by the other ships at the time when the data collections occured. In view of this, CV2 data was omitted, and a correlation matrix was generated using the data from the remaining four ships. This matrix is presented in Table 10 in Appendix B. Although none of the signs of the correlation coefficients examined were reversed by this process, the relative magnitudes of the associations between many of the variables improved.

---

[5]The five variables that did not agree with expected results are identified and discussed later in this section.

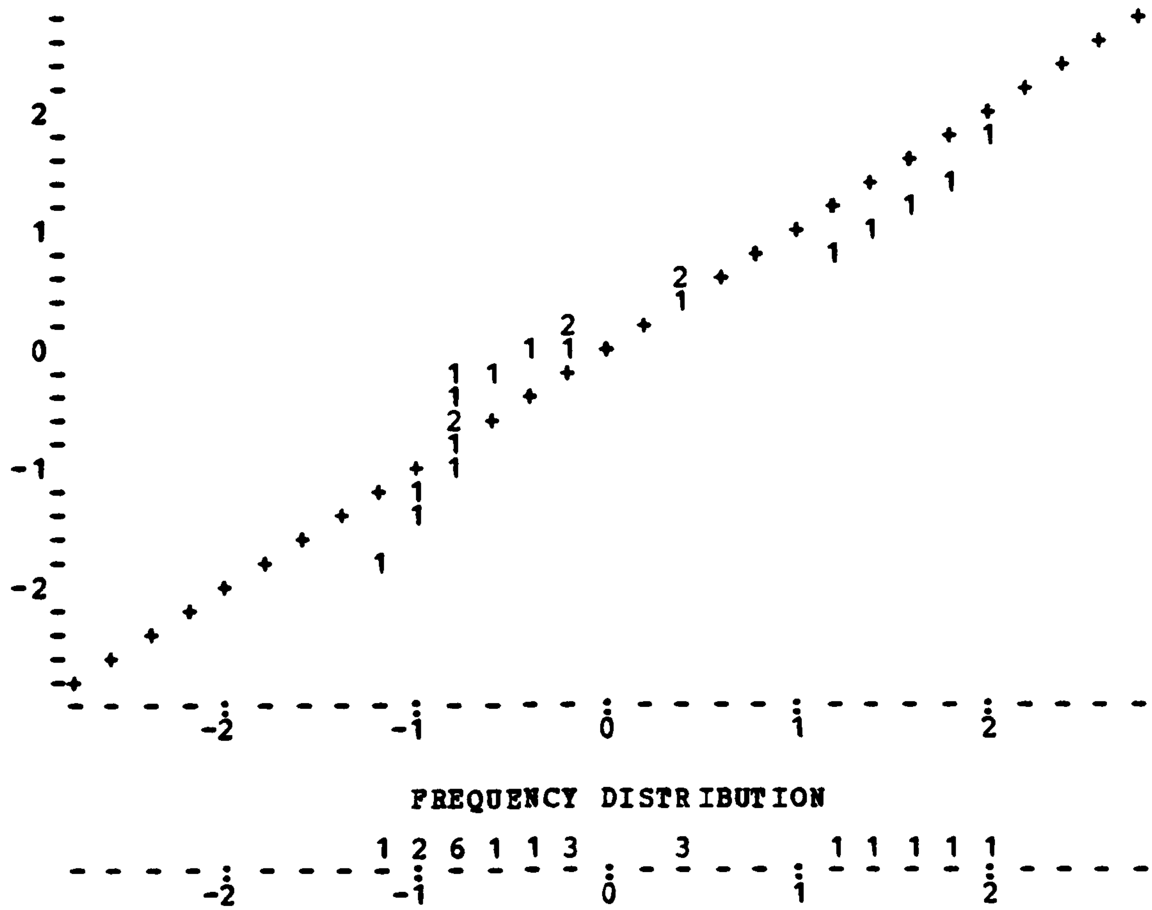
No apparent reason could be found which explained the erratic behavior of the CV3 data. An additional correlation matrix was generated from the data, this time excluding both the CV2 and CV3 data. This matrix (Table 11) shows much stronger associations between variables than those indicated by any of the previous matrices. Although the present study is severely limited by the number of available data observation sets, it was decided by the author that the objectives of the study could best be served by omitting the CV2 and CV3 data. Subsequent analyses have excluded these data.

One might argue that "throwing out" these observations, particularly the CV3 data, would tend to bias the analyses of this study in favor of the desired results. In a true statistical interpretation of this action, it does bias the study; however, one must realize that the study was already "biased" from the start. A major assumption of this study is that there is a relationship between aircraft readiness and Supply performance. Culling the data of "outliers" and inappropriate observations may "force" the results in the desired direction, but it may also reveal important or interesting relationships that might otherwise have been missed because of the "noise."

2. Tests for Normality

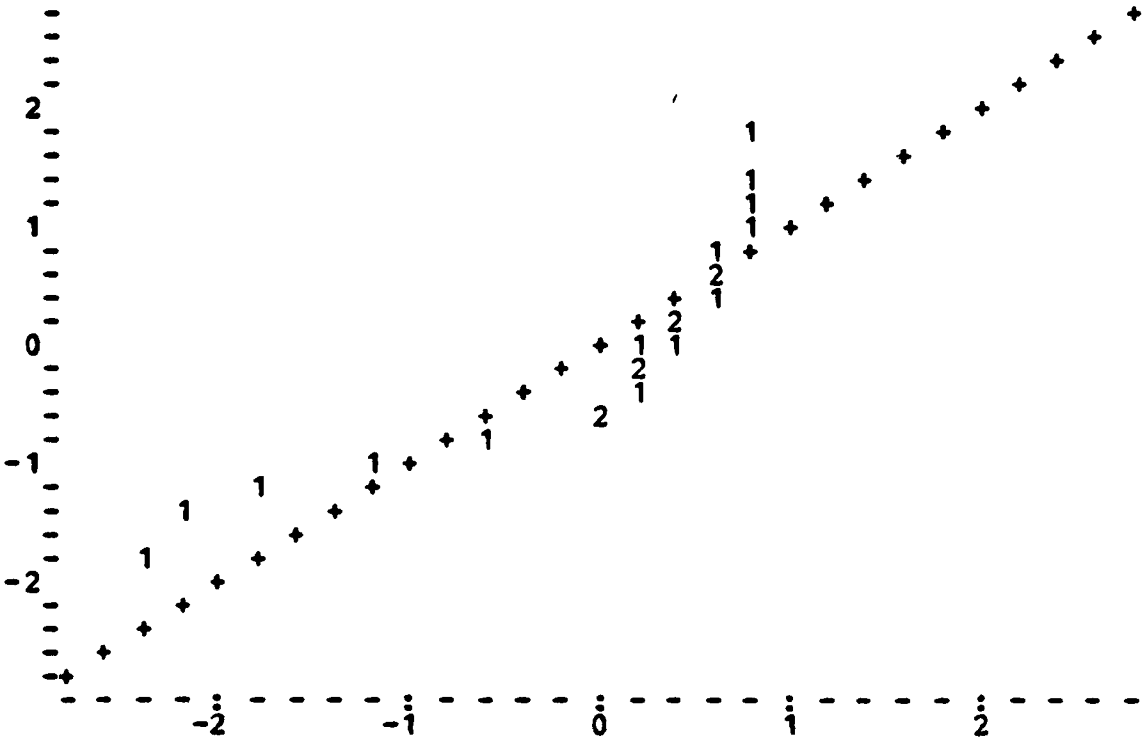
Normal probability plots (described in Section III) have been used to check the data for normality. Figures 2 and 3 are reproductions of IDA printouts[6] of the plots for the variables P/NMCS and PE, respectively. The P/NMCS plot is representative of the data plots for the variables

[6]These printouts were edited in order to reduce their size; however, none of the plotted values were altered in the process.

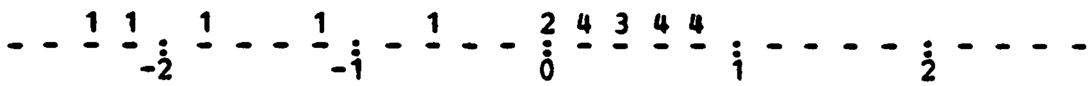



```
MEAN =  1.6264E+02
STD.DEV =   9.2099E+01
SKEWNESS =   7.4428E-01
KURTOSIS = -9.7670E-01
SAMPLE SIZE =  22
```

Figure 2.  Normal Probability Plot of the Variable P/NMCS




FREQUENCY DISTRIBUTION




```
MEAN = 8.7636E-01
STD.DEV = 8.2551E-02
SKEWNESS = -1.2997E+00
KURTOSIS = 2.4771E-01
SAMPLE SIZE = 22
```

Figure 3. Normal Probalility Plot of the Variable PE

which report "count" data, and the PE plot is similarly representative of the variables which report "rate" data. Recalling that normally distributed data will plot along the 45 degree diagonal (indicated in Figures 2 and 3 by "+" symbols) in a reasonably straight line, it can be seen that the data do not appear to have normal distributions. This is not very surprising because of the small number of available observations. For the case concerning the rate data, this result could be expected, since this type of data may take on values only between 0 and 1.

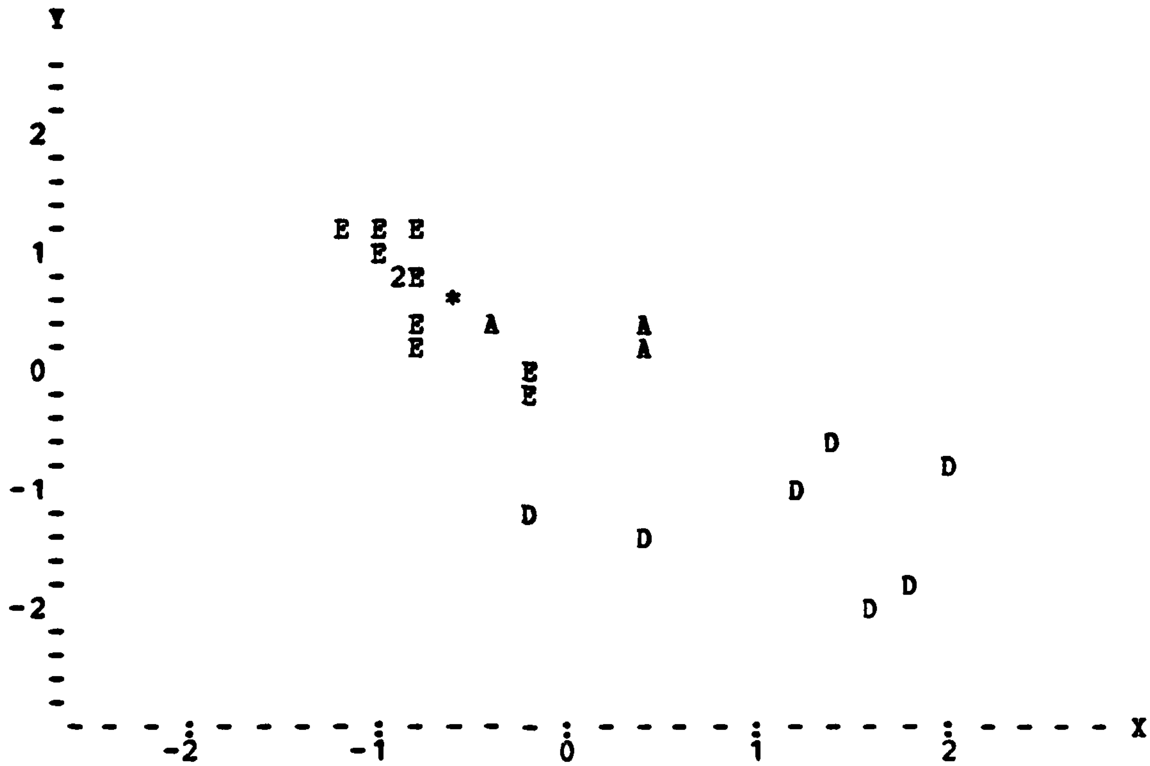
The reader may note that the IDA printouts also provide additional information concerning the frequency distribution of the data as well as the skewness and kurtosis of the distribution. These values may also be used to assess the presence of normality in the data, but they will not be discussed here.

Fortunately, the assumptions of normality here is not of paramount importance to the use of the t-statistics and the F-statistics, because they are reasonably robust statistical tools. Furthermore, the normal probability plots have not proved that the data come from populations that are distributed in a manner that differs from the Normal distribution. They have merely indicated that the available data do not appear to be normally distributed.

### 3. Explanation of Figures Used in the Analysis

Figure 4 is a sample of the majority of the figures used in this report to examine the relationships between two variables. These figures are reproductions of the actual IDA printouts, with minor alterations and editing performed to enable the information to fit on a single

4a. Scatter Plot of 22 Standardized Values of Y vs. X




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| Y | 0.0 | 1.000 | dimensionless | A: | CV1 |
| X | 162.64 | 92.099 | # of requisitions | D: | CV4 |
| | | | | E: | CV5 |
| | | | | *: | A,E |

4b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| X | -0.8318 | -4.4682E-04 | 6.6676E-05 | -6.701 | 1.725 |
| CONSTANT | 0 | 8.2267E-01 | 1.2393E-02 | 66.382 | |

4c. R-square Values:

UNADJUSTED: 0.6919 ADJUSTED: 0.6765

4d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 3.55620E-02 | 1 | 3.55620E-02 | | |
| RESIDUALS | 1.58379E-02 | 20 | 7.91897E-04 | 44.91 | 4.35 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

Figure 4. Sample Analysis of a Two-Variable Relationship

page. The actual values and regression results have not been changed. Each figure consists of the four parts explained below.

a. Scatter Plot of Standardized Values

Figure 4a shows the scatter plot of 22 standardized values of the variable Y versus the variable X. Since computer plotting is limited by the printer carriage, each plotted "symbol" represents a data value that was within the "grid" of the print character. Thus, the graph is a rough approximation of the precise location of data, but nonetheless provides a satisfactory representation of the data for the purposes of this study. The print characters that are normally used by IDA to indicate data on a plot are the arabic number symbols: "1" if a single value occured within the grid, "2" if two values occurred, and so on. These symbols have been replaced by the letters "A," "D," or "E" in order to identify the ship source (CV1, CV4, and CV5, respectively). If more than one value occurs at a location, the number of values occurring precedes the letter (e.g., "2E"), however, the location of the letter symbol (the "E" in "2E") marks the actual location where the values were observed. If more than one value occurs at a grid location, but they are from different ships, "*" is used, and the applicable ships are identified below the graph.

The reader may recall that the data is standardized by IDA prior to plotting, thus the scales of measure for both the ordinate (y-axis) and the abscissa (x-axis) are in terms of the respective standard deviations of the applicable data. This can be seen in Figure 4a. Both axes are scaled with the coordinates -2, -1, 0, 1, 2. These numbers represent respectively: two standard deviations below the mean, one

standard deviation below the mean, the mean value, one standard deviation above the mean, and two standard deviations above the mean. The mean value and standard deviation of each variable is indicated below the graph. The respective values of 0 and 1 are used for the mean and standard deviation in plots that include the variables MC or FMC for security reasons. The unit measure (e.g., number of components) for each variable is also listed below the graph. In this study, rate data will be treated as dimensionless.

b. Regression Coefficients

Figure 4b lists the coefficients of the regression model determined by regressing the variable Y on the variable X. The regression model can be represented by the equation:

$$Y = BX + \text{constant}. \qquad (14)$$

The regression coefficient, B, and the value of the constant term may be obtained from the third column (also labeled "B") of the table in Figure 4b. Using the sample values, equation 14 may be rewritten as:

$$Y = -.00044682X + .82267 \qquad (15)$$

where it is seen that in this sample, the coefficient of X takes on the negative sign that was indicated by the plot in Figure 4a.

Columns 2, 4, and 5 in Figure 4b list respectively the coefficients of the standardized variables, the standard error of the coefficients in column 3, and the t-statistic for the variables. The t-statistic was discussed in Section III, and the remaining columns will not be discussed except for a brief explanation of the relationship between the columns. The t-statistic (column 5) of each variable or the constant term in a regression model can be obtained by dividing the

applicable value of the regression coefficient (column 3, "B") by the corresponding standard error (column 4). The values in column 2 represent the regression coefficients of the variables that are obtained when the standardized values of data are used in a regression. The value in column 2 for the constant term will always equal zero. For single-variable regressions such as this sample, the coefficient of the standardized variable X is equal to the correlation coefficient between X and Y, and it is the square root of the R-square value that measures the goodness-of-fit. This is not the case for the multivariate regressions that will be seen later, yet the column 2 values still provide a measure of the relative "explanatory power" of a variable in a multiple variable regression.

A sixth column has been included in the table of Figure 4b, but it is not an end-product of the IDA package. This column (.95 T) indicates the value of the t-statistic at the 95th percentile of the Student's t distribution. Ninety-five percent of all possible values of the Student's t distribution are less than the 95th percentile value. The percentile value is determined by two factors: the percentile values desired and the total degrees of freedom. The total degrees of freedom in a regression model is a function of the number of variables used in a model and the number of observations used in the regression. It is computed by subtracting the number of variables (including the constant term) from the number of observations. In the sample regression, the total degrees of freedom is 20.

The 95th percentile value may be used to compute 95 percent confidence intervals for the regression coefficients. This is done by

multiplying the percentile value by the standard error of the regression coefficient. This product is then <u>subtracted</u> from the regression coefficient to obtain the lower limit of interval, and it is <u>added</u> to the regression coefficient in order to obtain the upper limit. The confidence intervals for the coefficients developed in this study have not been calculated. The purpose of the 95th percentile value in this study is to provide a basis for making statistical statements concerning the regression coefficients. If the t-statistic of the regression coefficient is <u>greater than</u> the 95th percentile value, it can then be stated that the regression coefficient is statistically differentiable from the value zero <u>and</u> that the <u>true value</u> of the coefficient will fall within the confidence interval 95 times out of 100. Thus, variables with a t-statistic that exceeds the applicable 95th percentile value will be considered in this study to be "significant to the model."

c. R-Square Values

Figure 4c indicates two R-square values. The first value (unadjusted) is simply the measure of the linear fit attained by the model without consideration to the number of variables in the model. The second value (adjusted) is a revised value of R-square that takes the number of variables into consideration. This is related to the concept of degrees of freedom. The adjusted R-square value allows the analyst to compare on an equal basis, the relative goodness-of-fit between two regression models that contain different numbers of variables.

d. Analysis of Variance

Figure 4d is the Analysis of Variance (ANOVA) table that is developed as an end-result of the regression process. The statistic of interest here is the F-statistic in the fifth column of the table, and it is calculated using several of the values in columns 2, 3, and 4. These columns are not discussed here, and the reader should consult one of the texts listed in the Bibliography for a complete explanation of ANOVA tables.

A sixth column (.95 F) has been included in Figure 4d and is similar to column 6 of Figure 4b. The 95th percentile value of the applicable F-statistic is listed in this column and is used in a manner that is similar to the t-statistic procedure, but it assesses the significance of the model in its entirety. Without explaining the "mechanics" behind the use of the 95th percentile F-value, the regression models that generate F-statistics greater than the 95th percentile value will be considered to be "significant." It should be noted that the F-statistic is closely related to the t-statistic. In <u>single-variable</u> regression models, the t-statistic for the regression variable is simply the square root of the F-statistic for the model.

## C. ANALYSIS OF SUPPORT FACTORS

An initial step in the analyses of the data base was to examine the relationships of the Support Factors, MSFA and CRF, with the aircraft readiness variables, MC and FMC. The results of these analyses are presented in this subsection. All analyses in this subsection and subsequent subsections are based on the 22 observations from the aircraft carriers CV1, CV4, and CV5.

1. Relationship Between Full Mission Capability and the Material Support Factor-Aviation

The correlation coefficient value for the variables FMC and MSFA listed in Table 11 is 0.44. This suggests that a positive linear relationship may exist between the variables. Figure 5 is a scatter plot of the data which does not identify the ship source for each value. When one examines this figure, there does indeed appear to be a definite trend to the data. However, if one examines the corresponding scatter plot in Figure 6, where each value is identified by the ship source, the relationship is no longer obvious. In fact, there appears to be no relationship between the Support Factor, MSFA, and Full Mission Capability, despite the fact that the F-statistic is above the 95th percentile value. The data from the three ships spread out horizontally at distinct values of Full Mission Capability. The R-square value of 0.1949 is low, indicating a poor fit of the regression model.

2. Relationship Between Mission Capability and the Material Support Factor-Aviation

Figure 7 shows the results of the analysis of the relationship between Mission Capability and the MSFA Support Factor. In this analysis, there is a slightly higher correlation coefficient (0.52) and correspondingly higher R-square and F-statistic values, but the same situation as in the previous analysis occurs here. Data from ship CV4 are grouped in a horizontal pattern below the mean value of MC, and the data from ships CV1 and CV5 are grouped horizontally above the mean. Once again, no apparent relationship can be observed.

AD-A124 629 MULTIVARIATE ANALYSES OF AFLOAT SUPPLY PERFORMANCE AND AIRCRAFT READINESS DATA(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA S W GUION OCT 82 2/3

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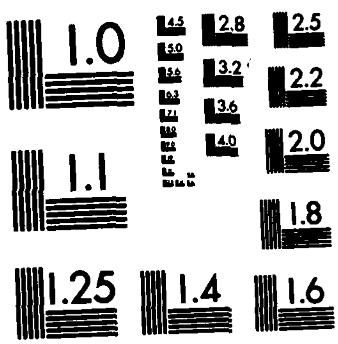
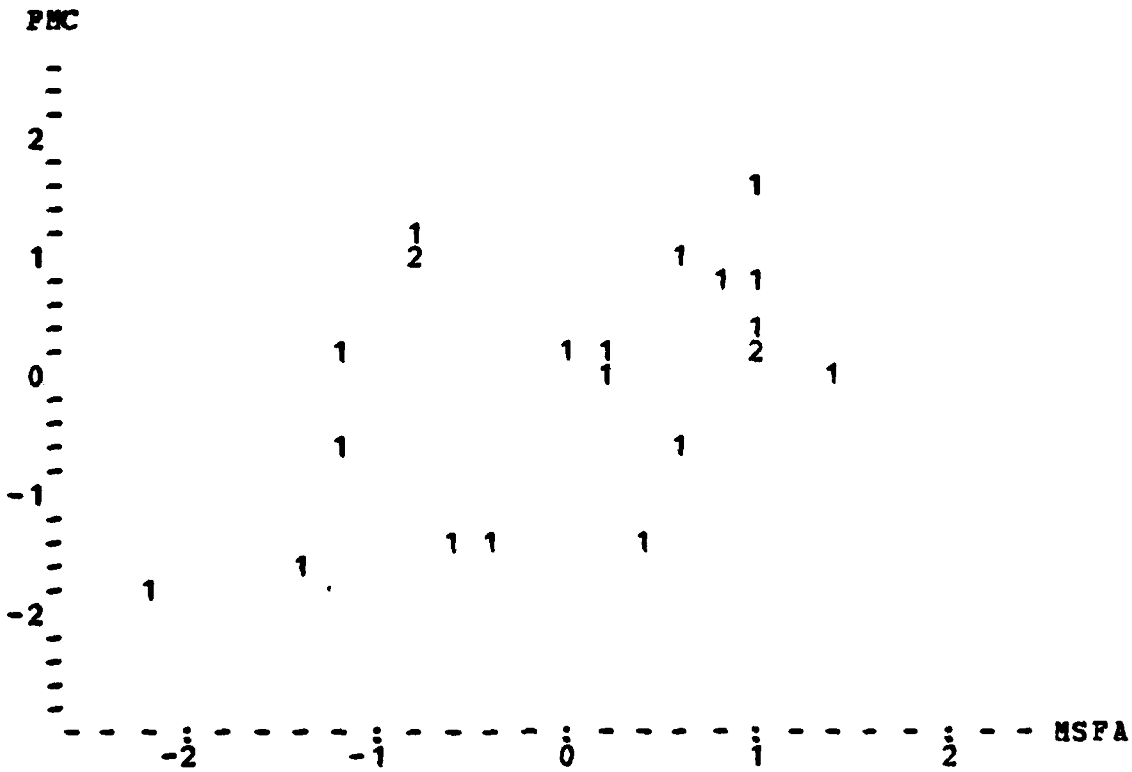



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

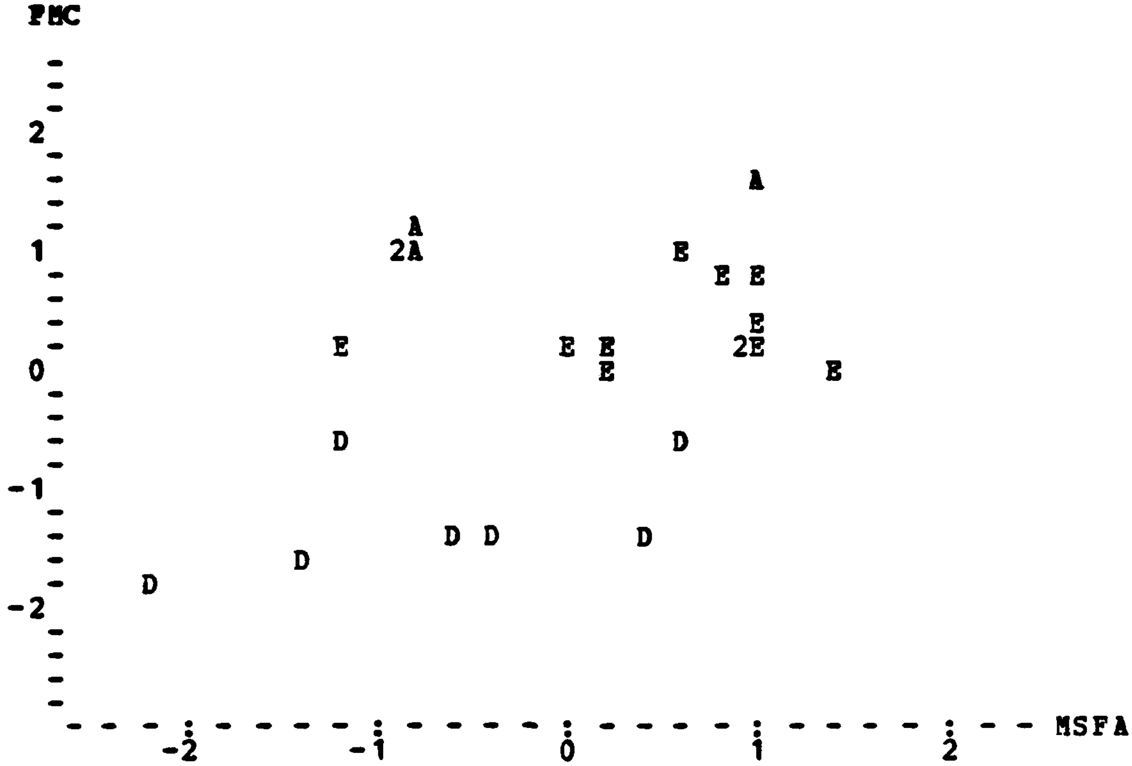



| | MEAN | STD. DEV. | UNITS |
|---|---|---|---|
| FMC | 0.0 | 1.00000 | dimensionless |
| MSFA | 0.78630 | 0.04443 | dimensionless |

Figure 5.

Scatter Plot of 22 Standardized Values of FMC vs. MSFA

6a. Scatter Plot of 22 Standardized Values of FMC vs. MSFA




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| FMC | 0.0 | 1.00000 | dimensionless | A: | CV1 |
| MSFA | 0.78630 | 0.04443 | dimensionless | D: | CV4 |
| | | | | E: | CV5 |

6b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| MSFA | 0.4414 | 6.3096E-01 | 2.8680E-01 | 2.200 | 1.725 |
| CONSTANT | 0 | 1.4751E-01 | 2.2585E-01 | 0.653 | |

6c. R-square Values:

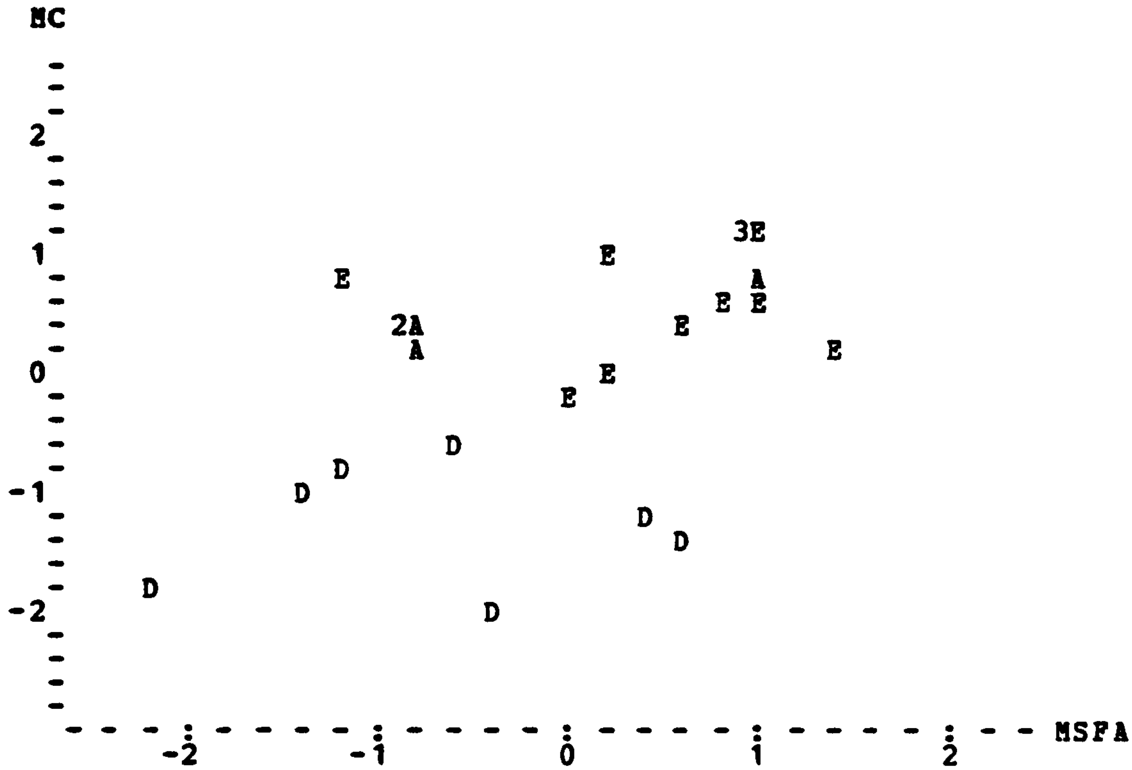
UNADJUSTED: 0.1949 ADJUSTED: 0.1546

6d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 1.65055E-02 | 1 | 1.65055E-02 | | |
| RESIDUALS | 6.82032E-02 | 20 | 3.41016E-03 | 4.84 | 4.35 |
| TOTAL | 8.47086E-02 | 21 | 4.03374E-03 | | |

Figure 6. Analysis of the Relationship Between FMC and MSFA

7a. Scatter Plot of 22 Standardized Values of MC vs. MSFA




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| MC | 0.0 | 1.00000 | dimensionless | A: | CV1 |
| MSFA | 0.78630 | 0.04443 | dimensionless | D: | CV4 |
| | | | | E: | CV5 |

7b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| MSFA | 0.5174 | 5.7613E-01 | 2.1305E-01 | 2.704 | 1.725 |
| CONSTANT | 0 | 2.9699E-01 | 1.6778E-01 | 1.770 | |

7c. R-square Values:

UNADJUSTED: 0.2677 ADJUSTED: 0.2311

7d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 1.37616E-02 | 1 | 1.37616E-02 | | |
| RESIDUALS | 3.76384E-02 | 20 | 1.88192E-03 | 7.31 | 4.35 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

Figure 7. Analysis of the Relationship Between MC and MSFA

3. <u>Relationship Between Full Mission Capability and the Component Repair Factor</u>

Figure 8 shows the results of this analysis, which speaks for itself. No relationship between Full Mission Capability and the Component Repair Factor is indicated by the data.

4. <u>Relationship Between Mission Capability and the Component Repair Factor</u>

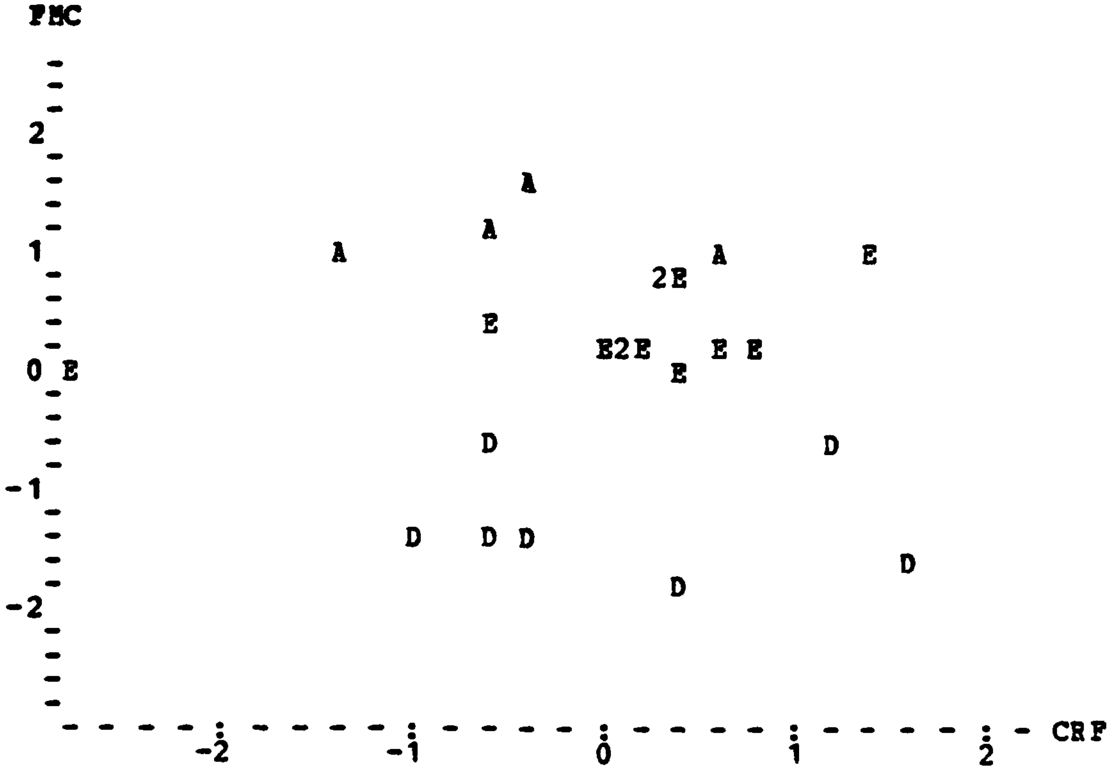
The results of this analysis are listed in Figure 9. Like the three previous analyses, the data do not suggest any relationship between these variables.

## D. SELECTION OF A DEPENDENT VARIABLE

Since the preceding analyses yielded negative results, it was decided to make further investigations of the variables which are used to compute the Support Factors. At this point, however, it was decided that analyses using both MC and FMC would be a duplication of effort, particularly since the correlation between the two variables was high (0.80).

The next step was to decide which of the readiness variables to use in subsequent analyses. Since an aircraft that is in FMC status must also be in MC status, it seemed natural to model FMC as a function of MC. This was attempted, and the results are listed in Figure 10. Once again, the data from each of the ships is somewhat clustered, but there is a definite trend to the clustering. It is interesting to note that although ship CV1 has a high correlation coefficient for MC and FMC (0.87), the trend is not immediately obvious from the corresponding correlation coefficients for ships CV4 and CV5 (0.39 and 0.31, respectively). The R-square value of 0.6476 indicates a reasonably good fit of the linear model. The correspondingly high F-statistic of 36.75 supports

8a. Scatter Plot of 22 Standardized Values of FMC vs. CRF




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| FMC | 0.0 | 1.00000 | dimensionless | A: | CV1 |
| CRF | 0.71852 | 0.07500 | dimensionless | D: | CV4 |
| | | | | E: | CV5 |

8b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| CRF | -0.0518 | -4.3868E-02 | 1.8911E-01 | -0.232 | 1.725 |
| CONSTANT | 0 | 6.7516E-01 | 1.3658E-01 | 4.943 | |

8c. R-square Values:

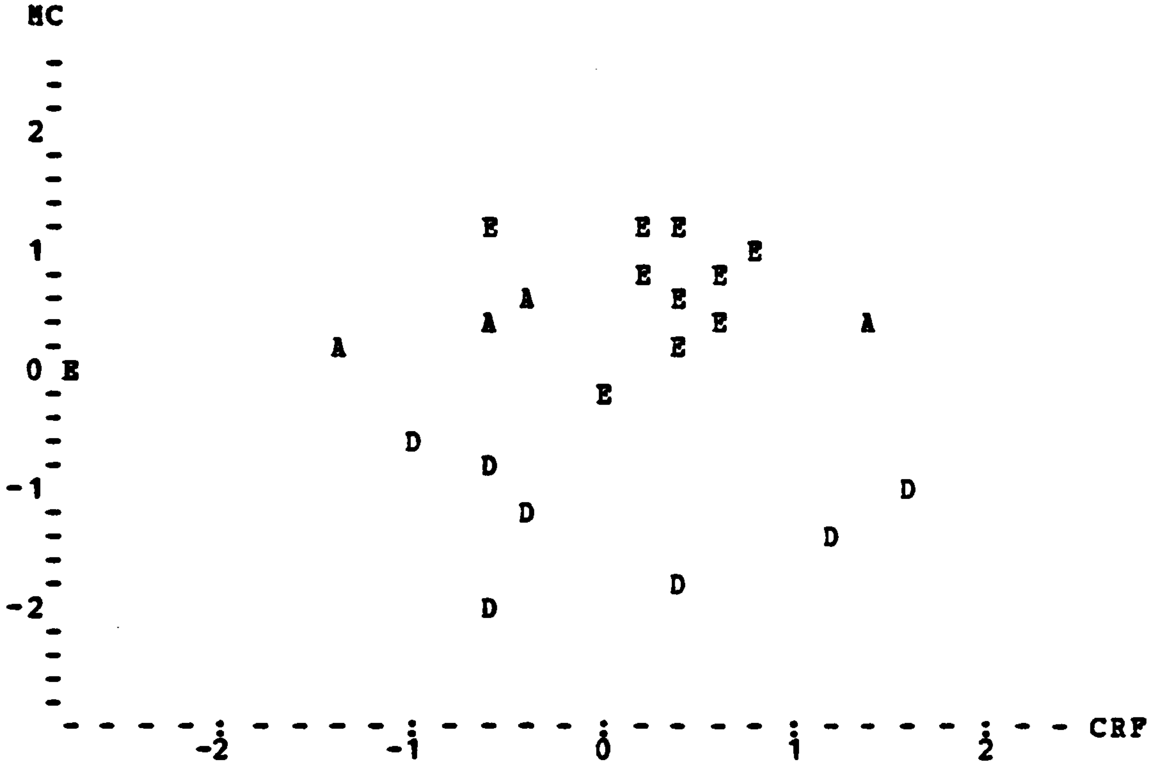
UNADJUSTED: 0.0027 ADJUSTED: 0.0

8d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 2.27332E-04 | 1 | 2.27332E-04 | | |
| RESIDUALS | 8.44813E-02 | 20 | 4.22406E-03 | 0.05 | 4.35 |
| TOTAL | 8.47086E-02 | 21 | 4.03374E-03 | | |

Figure 8. Analysis of the Relationship Between FMC and CRF

9a. Scatter Plot of 22 Standardized Values of MC vs. CRF




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| MC | 0.0 | 1.00000 | dimensionless | A: | CV1 |
| CRF | 0.71852 | 0.07500 | dimensionless | D: | CV4 |
| | | | | E: | CV5 |

9b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| CRF | 0.0266 | 1.7567E-02 | 1.4745E-01 | 0.119 | 1.725 |
| CONSTANT | 0 | 7.3738E-01 | 1.0650E-01 | 6.924 | |

9c. R-square Values:

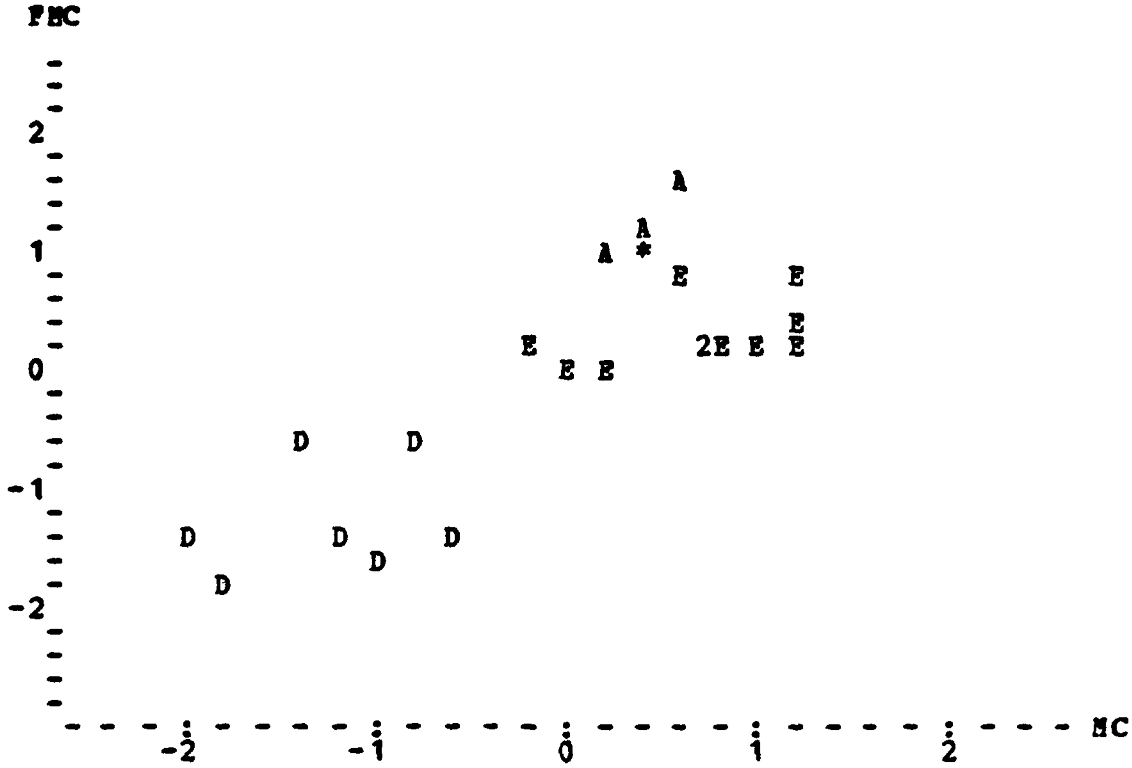
UNADJUSTED: 0.0007 ADJUSTED: 0.0

9d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 3.64520E-05 | 1 | 3.64520E-05 | | |
| RESIDUALS | 5.13635E-02 | 20 | 2.56817E-03 | 0.01 | 4.35 |
| TCTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

Figure 9. Analysis of the Relationship Between MC and CRF

10a. Scatter Plot of 22 Standardized Values of FMC vs. MC




| | MEAN | STD. DEV. | UNITS |
|---|---|---|---|
| FMC | 0.0 | 1.00000 | dimensionless |
| MC | 0.0 | 1.00000 | dimensionless |

A: CV1
D: CV4
E: CV5
*: A,E

10b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| MC | 0.8047 | 1.0331E+00 | 1.7041E-01 | 6.062 | 1.725 |
| CONSTANT | 0 | -1.3117E-01 | 1.2807E-01 | -1.024 | |

10c. R-square Values:

UNADJUSTED: 0.6476 ADJUSTED: 0.6300

10d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 5.48558E-02 | 1 | 5.48558E-02 | | |
| RESIDUALS | 2.98528E-02 | 20 | 1.49264E-03 | 36.75 | 4.35 |
| TOTAL | 8.47086E-02 | 21 | 4.03374E-03 | | |

Figure 10. Analysis of the Relationship Between FMC and MC

the significance of the model. Based on these results, the variable MC was selected for further analyses.

## E. RELATIONSHIP BETWEEN MISSION CAPABILITY AND PERFORMANCE VARIABLES

In this subsection, the data are used in several linear multivariate regression models to suggest possible alternative combinations of variables for use in the Support Factors. The objective here is to identify combinations of variables which yield singular statistics that are related to aircraft readiness more strongly than the relationships observed between MC and the Support Factors currently in use. First, the relationships between the variable MC and the variables that are currently used to compute the Support Factors are examined. This is followed by a look at the relationship of MC with all performance variables.

### 1. Relationship Between MC and MSFA Input Variables

In Section II, the Material Support Factor-Aviation (MSFA) was introduced, and was seen in equation (12) to be the weighted average of ten of the performance variables:

$$MSFA = \frac{4(AN + AG + CN + PE) + AR + AX + CR + CX + PR + PX}{22} . \quad (16)$$

Since this combination of variables relates poorly to readiness, the variable MC was regressed on the ten input variables in order to see if a better weighted average was suggested by the data. The results of this regression are presented in Figure 11. Figure 11 does not include a scatter plot, because the relationship between more than two variables cannot be represented by a single graph.

There are several problems with the model obtained. Although the unadjusted R-square value is good, the adjustment for the number of

11a. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| AN | -0.9241 | -6.4624E-01 | 3.3271E-01 | -1.942 | 1.796 |
| AG | 1.1925 | 7.0673E-01 | 3.3981E-01 | 2.080 | |
| CN | -0.0823 | -5.5271E-02 | 1.7710E-01 | -0.312 | |
| PE | 0.2358 | 1.4133E-01 | 2.0668E-01 | 0.684 | |
| AR | 0.4906 | 2.9122E-01 | 3.0903E-01 | 0.942 | |
| AX | -0.4512 | -4.6873E-01 | 4.7744E-01 | -0.982 | |
| CR | -0.3405 | -4.2863E-01 | 3.4282E-01 | -1.250 | |
| CX | 0.4431 | 4.4530E-01 | 4.0343E-01 | 1.104 | |
| PR | -0.0471 | -3.4696E-02 | 2.3912E-01 | -0.145 | |
| PX | 0.3247 | 1.3976E-01 | 1.9241E-01 | 0.726 | |
| CONSTANT | 0 | 7.6826E-01 | 4.0480E-01 | 1.898 | |

11b. R-square Values:

UNADJUSTED: 0.6672 ADJUSTED: 0.3646

11c. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 3.42928E-02 | 10 | 3.42928E-03 | | |
| RESIDUALS | 1.71071E-02 | 11 | 1.55519E-03 | 2.21 | 2.86 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

11d. Correlation Between MC and Input Variables:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AN: | 0.06 | AX: | 0.39 | CX: | -0.35 | PX: | 0.54 |
| AG: | 0.28 | CN: | 0.36 | PE: | 0.55 | | |
| AR: | 0.60 | CR: | -0.47 | PR: | 0.21 | | |

11e. Variable Pairs with Large Correlation:

| | | | | | |
|---|---|---|---|---|---|
| AG/AN: | 0.88 | PE/PR: | 0.59 | AR/CN: | 0.56 |
| AR/AX: | 0.79 | AG/AX: | 0.58 | AR/PX: | 0.51 |
| PE/PX: | 0.77 | AG/CX: | -0.58 | AN/AX: | 0.50 |
| PR/PX: | 0.68 | CR/CX: | 0.58 | AX/CN: | -0.49 |
| AR/CR: | -0.59 | AG/AR: | 0.56 | CN/CR: | -0.49 |
| | | | | CN/PE: | 0.49 |

Figure 11. Analysis of the Relationship Between MC and the Input Variables of the Material Support Factor-Aviation

variables in the model suggests that other models with fewer variables may provide a better linear relationship with MC. The low F-statistic suggests that the regression coefficients of the model cannot be statistically differentiated from the value zero, and this is reiterated by the fact that eight out of ten regression coefficients have t-statistic values below the 95th percentile.

Aside from the fact that the model is poor, the truly disturbing result is the negative signs of the coefficients which occur for five of the variables. The intuitive relationships of these variables with MC suggest that all of the coefficients should have positive signs. This is supported by the correlation coefficients of the input variables with MC, which have been extracted from Table 11 and are listed in Figure 11d. Only the variables CR and CX indicate a negative relationship with MC.

The real problems with this model and, quite possibly, the current MSFA model, are brought about by the poor explanatory power of the ten input variables and the multiple correlations exhibited between them. Of the ten variables used to compute the Support Factor, only four of them (AR, CR, PE, and PX) have what could be considered only moderate explanatory power in relation to the variable MC. This alone suggests that any model that uses these ten variables will not exhibit a very strong relationship to readiness.

Furthermore, a large amount of multicolinearity exists in the data, as evidenced by Figure 11e. In this figure, the 16 largest values of positive and negative correlation coefficients between the input variables have been taken from Table 11. It is clear from Figure 11e, that there are many interactions going on between the variables. The

effect of these interactions can be seen in the regression coefficients in Figure 11b. For example, the variables CR and CX, which have a correlation coefficient of 0.58, have nearly identical regression coefficient values but are of <u>opposite</u> sign. The end result is that the two variables effectively cancel each other out of the equation. The same situation can be observed between the variables AG and AN, which have a correlation coefficient of 0.88. Although the absolute values of the regression coefficients are not as close to each other as in the previous example, the effect is nearly the same.

The poor results generated by this model did not lead the author to completely discard the input variables. Several of the variables did exhibit some degree of explanatory power. The IDA package provides an option which allows the analyst to remove variables one-by-one from a regression model. This procedure was used on the model of Figure 11 in order to eliminate highly correlated variables in an attempt to find a subset of the ten variables which both agreed with the intuitive positive signs and maintained a significant linear relationship with aircraft readiness. Figure 12 presents the final results of this analysis, which developed three regression models that satisfied the selection criteria to the greatest extent.

Figures 12a, 12b, and 12c show a three-variable model which uses the variables AG, AR, and PE. In this model, all of the signs of the regression coefficients are positive, the F-statistic of 5.18 (Figure 12c) is significantly above the 95th percentile value, and the adjusted R-square value of 0.3737 (Figure 12b) indicates that this linear model "fits" the applicable data slightly better than the ten-variable model.

12a. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PE | 0.3847 | 2.3056E-01 | 1.2422E-01 | 1.856 | 1.734 |
| AG | 0.0857 | 5.0771E-02 | 1.3387E-01 | 0.379 | |
| AR | 0.3836 | 2.2770E-01 | 1.4837E-01 | 1.535 | |
| CONSTANT | 0 | 3.1758E-01 | 1.1405E-01 | 2.785 | |

12b. R-square Values:

UNADJUSTED: 0.4632 ADJUSTED: 0.3737

12c. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 2.38061E-02 | 3 | 7.93535E-03 | | |
| RESIDUALS | 2.75939E-02 | 18 | 1.53299E-03 | 5.18 | 3.16 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

12d. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PE | 0.5602 | 3.3572E-01 | 1.0725E-01 | 3.130 | 1.724 |
| AG | 0.3088 | 1.8300E-01 | 1.0605E-01 | 1.726 | |
| CONSTANT | 0 | 3.4507E-01 | 1.1658E-01 | 2.960 | |

12e. R-square Values:

UNADJUSTED: 0.3929 ADJUSTED: 0.3290

12f. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 2.01953E-02 | 2 | 1.00977E-02 | | |
| RESIDUALS | 3.12046E-02 | 19 | 1.64235E-03 | 6.15 | 3.52 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

12g. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PE | 0.3544 | 2.1242E-01 | 1.1203E-01 | 1.896 | 1.724 |
| AR | 0.4446 | 2.6391E-01 | 1.1096E-01 | 2.378 | |
| CONSTANT | 0 | 3.3244E-01 | 1.0467E-01 | 3.176 | |

12h. R-square values:

UNADJUSTED: 0.4589 ADJUSTED: 0.4019

12i. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 2.35855E-02 | 2 | 1.17928E-02 | | |
| RESIDUALS | 2.78144E-02 | 19 | 1.46392E-03 | 8.06 | 3.52 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

Figure 12. Regression Analyses of Mission Capability with the Variables AG, AR, and PE

Even though this model is relatively simple, a significant amount of multicolinearity remains. The variables AG and AR have a correlation coefficient of 0.56, and the corresponding correlation between the variables PE and AR is 0.43. This may explain the relatively low t-statistic values for both AG and AR.

The next step in this analysis involved selecting one of the variables from the model of Figure 12a and removing it. The general criterion that is often used for selecting a variable to be removed is to pick the variable with the lowest absolute t-statistic value, since that variable normally is the one which "contributes" the least to the model. According to this procedure, the variable AG should have been removed at this point, since the t-statistic value in Figure 12a is 0.379. However, the correlation between AG and PE is only -0.05, which is much lower than the 0.43 correlation between AR and PE. This led the author to believe that virtually all multicolinearity in the model could be eliminated by removing AR, instead of AG, so this was attempted.

Figures 12d, 12e, and 12f are the regression results of the two-variable model using PE and AG. In this model, both the F-statistic and the t-statistics are above their respective 95th percentile values; however, there is some reduction in the adjusted R-square value of Figure 12e (0.3290). In fact, this value has fallen below the adjusted value of the ten-variable model (0.3646). Apparently, removing AR from the model has reduced the multicolinearity of the model, but the resulting linear fit has suffered in the process.

Finally, a regression was performed using PE and AG, which was the model suggested originally by the low t-statistic criterion.

The results of this regression are shown in Figures 12g, 12h, and 12i. In this model, both variables have significant t-statistic values, and the corresponding F-statistic value is the highest of any model examined. The pleasing result here is that the adjusted R-square value (0.4019) of Figure 12h has increased and is higher than both the ten-variable model and the three-variable model. Even so, this value does not indicate that the linear model fits the applicable data very well, but it is the "best" one found to this point. It can be stated, then, that the data indicate that POOL Effectiveness and AVCAL Range both have a statistically significant relationship to Mission Capability and that the relative association of each of these variables with MC is approximately the same. This is based on the regression coefficients of the variables in Figure 12g which are nearly the same in magnitude.

2. Relationship Between MC and CRF Input Variables

An analysis of the relationship between Mission Capability and the input variables of the Component Repair Factor was performed in a procedure identical to the analyses of the MSFA input variables. It will be recalled from Section II that the equation for CRF is given by:

$$CRF = \frac{3(1 - PZBR) + MR - MP - 2MM}{4} . \qquad (17)$$

The CRF input variables PZBR, MR, MP, and MM were used in a four-variable regression model with MC as the dependent variable. The results of this regression are shown in Figure 13. It is seen from the adjusted R-square value (0.6621) of Figure 13b that the linear model fits the data quite well, and from Figure 13c the corresponding F-statistic value (11.28) is high. However, the t-statistic values for the variables,

13a. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PZBR | -0.3079 | -2.1364E-01 | 9.6153E-02 | -2.222 | 1.740 |
| MR | -0.7233 | -5.3567E-01 | 1.2683E-01 | -4.224 | |
| MP | -0.2222 | -1.2577E-01 | 1.0865E-01 | -1.158 | |
| MM | 0.0072 | 4.3544E-03 | 1.3708E-01 | 0.032 | |
| CONSTANT | 0 | 1.1665E+00 | 9.2646E-02 | 12.591 | |

13b. R-square Values:

UNADJUSTED: 0.7265 ADJUSTED: 0.6621

13c. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 3.73396E-02 | 4 | 9.33489E-03 | | |
| RESIDUALS | 1.40604E-02 | 17 | 8.27082E-04 | 11.29 | 2.96 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

13d. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PZBR | -0.3080 | -2.1366E-01 | 9.3445E-02 | -2.286 | 1.734 |
| MR | -0.7262 | -5.3777E-01 | 1.0518E-01 | -5.113 | |
| MP | -0.2178 | -1.2331E-01 | 7.4156E-02 | -1.663 | |
| CONSTANT | 0 | 1.1682E+00 | 7.3576E-02 | 15.878 | |

13e. R-square Values:

UNADJUSTED: 0.7264 ADJUSTED: 0.6808

13f. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 3.73387E-02 | 3 | 1.24462E-02 | | |
| RESIDUALS | 1.40612E-02 | 18 | 7.81179E-04 | 15.93 | 3.16 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

Figure 13. Analysis of the Relationship Between MC and the Input Variables of the Component Repair Factor

MP and MM, are low. This observation, combined with the 0.74 correlation between MP and MM, again indicates multicolinearity in the model.

The real problem in this model is the negative sign of the regression coefficient for the variable MR. The reader will recall that MR represents the repair rate during a given month for a ship's repair activity. It should also be recalled that suspicion was raised concerning the usefulness of this variable, because the data it carries is not truly representative of any single month. From Table 11 in Appendix B, it is seen that the correlation coefficient between MR and MC is -0.78. This correlation is quite large, and the negative sign of the correlation accounts for the negative value of the regression coefficient. However, this negative correlation defies intuitive logic. In other words, the data indicate that as the rate of repaired components increases, Mission Capability decreases. This suggests that the Repair Rate variable, MR, is an extremely poor indicator of performance and may invalidate any regression that includes the variable.

Several regressions using subsets of the CRF input variables were performed, but obtained results similar to those obtained from the four-variable model. One of these models, which uses the variables PZBR, MR, and MP, is presented without comments in Figures 13d, 13e, and 13f.

### 3. Forward and Backward Regression Analyses of Mission Capability With the Performance Variables

The analyses of the relationships between Mission Capability and the performance variables were expanded at this point to include all of the variables in the data base, with the exception of the Support Factors. Using the forward and backward regression techniques explained in Section III, several linear regression models were suggested by the

data. Because only 22 observations were used in the regressions, the entire set of 28 available variables could not be incorporated in any single model; thus several forward and backward regressions were performed, using various subsets of the variables.

Figures 14 through 17 are representative forward and backward regressions that were performed. Figures 14 and 15 are the respective forward and backward regressions on one subset of 20 variables. Figures 16 and 17 are corresponding regressions on a different subset of 20 variables. The variables used for each regression are indicated in the respective figures. These figures have been edited, and several iterations have been omitted in favor of presenting the more interesting or significant results. Those iterations that were omitted each contained one or more variables with low t-statistic values.

These figures will not be discussed in this report. They are included as items of record, but they also serve as examples of the results which directed the author to the sequence of analyses presented in the next subsection. By this point, the reader should have some idea of which models "say more" than others. All of the linear regression models in Figures 14 through 17 have significantly high F-statistic values and many indicate extremely good "fits," particularly the model in Figure 17a. The reader should keep in mind, however, that all of the models that have more than three (or even two) variables have high multicolinearity. These models do not agree with the "real world" in terms of the relationships that are suggested between many of the variables and Mission Capability. It should also be remembered that although a regression model with a large number of variables may, in fact, explain

Variables Regressed: P/NMCS, AG, AN, AR, AX, AWMC, AWPC, AWP60, CG, CN, COM, CR, CX, MM, MP, MR, PE, PR, PX, PZBR

14a. First Iteration:

R-square = 0.6919 F = 44.91 .95 F = 4.35

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8318 | -4.4682E-04 | 6.6676E-05 | -6.701 | 1.725 |
| CONSTANT | 0 | 8.2267E-01 | 1.2393E-02 | 66.382 | |

14b. Second Iteration:

R-square = 0.7691 F = 31.66 .95 F = 3.52

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.6475 | -3.4783E-04 | 7.1025E-05 | -4.897 | 1.729 |
| COM | -0.3336 | -8.4144E-06 | 3.3351E-06 | -2.523 | |
| CONSTANT | 0 | 8.3376E-01 | 1.1850E-02 | 70.358 | |

14c. Third Iteration:

R-square = 0.9052 F = 27.23 .95 F = 3.16

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.9242 | -4.9646E-04 | 9.2620E-05 | -5.360 | 1.734 |
| COM | -0.3594 | -9.0661E-06 | 3.0448E-06 | -2.978 | |
| PX | -0.3679 | -1.5834E-01 | 7.0768E-02 | -2.237 | |
| CONSTANT | 0 | 9.9441E-01 | 7.2604E-02 | 13.696 | |

14d. Sixth Iteration:

R-square = 0.8830 F = 18.87 .95F = 2.79

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.9558 | -5.1345E-04 | 8.7959E-05 | -5.837 | 1.753 |
| COM | -0.3296 | -8.3139E-06 | 3.3767E-06 | -2.462 | |
| PX | -0.4218 | -1.8153E-01 | 6.4558E-02 | -2.812 | |
| CG | -0.2592 | -2.5354E-01 | 1.1709E-01 | -2.165 | |
| CR | -0.2442 | -3.0743E-01 | 1.5281E-01 | -2.012 | |
| AWP60 | -0.2300 | -2.5234E-04 | 1.2820E-04 | -1.968 | |
| CONSTANT | 0 | 1.5034E+00 | 2.0320E-01 | 7.399 | |

14e. Tenth Iteration:

R-square = 0.9596 F = 26.13 .95 F = 2.86

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8433 | -4.5301E-04 | 7.1316E-05 | -6.352 | 1.796 |
| COM | -0.5470 | -1.3797E-05 | 2.7040E-06 | -5.103 | |
| PX | -0.2574 | -1.1078E-01 | 4.7738E-02 | -2.321 | |
| CG | -0.2145 | -2.0980E-01 | 1.1518E-01 | -1.822 | |
| CR | -0.5565 | -7.0051E-01 | 1.4362E-01 | -4.877 | |
| AWP60 | -0.4063 | -4.4572E-04 | 1.0704E-04 | -4.164 | |
| CN | -0.3112 | -2.0892E-01 | 8.0727E-02 | -2.588 | |
| AWMC | 0.3774 | 1.0725E-04 | 3.1905E-05 | 3.361 | |
| AG | 0.1990 | 1.1792E-01 | 5.1649E-02 | 2.283 | |
| MP | -0.1936 | -1.0962E-01 | 4.8873E-02 | -2.243 | |
| CONSTANT | 0 | 1.8733E+00 | 1.7672E-01 | 10.600 | |

Figure 14. Selected Iterations of MC Forward Regression

Variables Regressed: P/NMCS, AG, AN, AR, AX, AWMC, AWPC, AWP60, CG, CN, COM, CR, CX, MM, MP, MR, PE, PR, PX, PZBR

15a. Fourth Iteration:

R-square = 0.9759 F = 44.53 .95 F = 2.86

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.3785 | -2.0334E-04 | 4.6339E-05 | -4.388 | 1.796 |
| PZBR | -0.5943 | -4.1230E-01 | 6.6109E-02 | -6.237 | |
| AN | 0.2321 | 1.6229E-01 | 4.7951E-02 | 3.384 | |
| MP | -0.4781 | -2.7065E-01 | 3.9538E-02 | -6.845 | |
| COM | -0.4245 | -1.0707E-05 | 2.8190E-06 | -3.798 | |
| AWMC | 0.7885 | 2.2404E-04 | 2.9536E-05 | 7.585 | |
| AWPC | -0.6474 | -1.8527E-04 | 3.5223E-05 | -5.260 | |
| CX | -0.2087 | -2.0973E-01 | 6.9740E-02 | -3.007 | |
| CG | -0.7423 | -7.2604E-01 | 8.7808E-02 | -8.269 | |
| CR | -0.6572 | -8.2731E-01 | 1.1396E-01 | -7.260 | |
| CONSTANT | 0 | 2.3081E+00 | 1.5983E-01 | 14.441 | |

15b. Fourteenth Iteration:

R-square = 0.9035 F = 18.71 .95 F = 2.77

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.5144 | -2.7634E-04 | 7.3284E-05 | -3.771 | 1.761 |
| PZBR | -0.4505 | -3.1253E-01 | 8.4047E-02 | -3.719 | |
| CR | -0.6279 | -7.9037E-01 | 1.8795E-01 | -4.205 | |
| MP | -0.3502 | -1.9828E-01 | 6.6390E-02 | -2.987 | |
| CG | -0.4871 | -4.7639E-01 | 1.3123E-01 | -3.630 | |
| AWMC | 0.5498 | 1.5623E-04 | 4.6511E-05 | 3.359 | |
| AWPC | -0.6989 | -2.0001E-04 | 4.1222E-05 | -4.852 | |
| CONSTANT | 0 | 1.9978E+00 | 2.5977E-01 | 7.690 | |

15c. Eighteenth Iteration:

R-square = 0.7614 F = 19.16 .95 F = 3.16

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.5656 | -3.0381E-04 | 8.9060E-05 | -3.411 | 1.734 |
| PZBR | -0.1628 | -1.1297E-01 | 9.6967E-02 | -1.165 | |
| AWPC | -0.2907 | -8.3186E-05 | 4.1160E-05 | -2.021 | |
| CONSTANT | 0 | 8.4745E-01 | 1.5796E-02 | 53.651 | |

15d. Nineteenth Iteration:

R-square = 0.7436 F = 27.54 .95 F = 3.52

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.6619 | -3.5555E-04 | 7.7916E-05 | -4.563 | 1.724 |
| AWPC | -0.2838 | -8.1206E-05 | 4.1510E-05 | -1.956 | |
| CONSTANT | 0 | 8.4029E-01 | 1.4686E-02 | 57.218 | |

15e. Twentieth Iteration:

R-square = 0.6919 F = 44.91 .95 F = 4.35

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8318 | -4.4681E-04 | 6.6675E-05 | -6.701 | 1.725 |
| CONSTANT | 0 | 8.2267E-01 | 1.2393E-02 | 66.383 | |

Figure 15. Selected Iterations of MC Backward Regression

Variables Regressed: P/NMCS, AD, AG, AR, AVLI, AX, AWMC, AWPC, AWP30, CG, COM, CR, CX, MM, MP, MR, PD, PE, POLI, PZBR

16a. First Iteration:

R-square = 0.6919  F = 44.91  .95 F = 4.35

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8318 | -4.4682E-04 | 6.6676E-05 | -6.701 | 1.725 |
| CONSTANT | 0 | 8.2267E-01 | 1.2393E-02 | 66.382 | |

16b. Second Iteration:

R-square = 0.7691  F = 31.66  .95 F = 3.52

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.6475 | -3.4783E-04 | 7.1025E-05 | -4.897 | 1.729 |
| COM | -0.3336 | -8.4144E-06 | 3.3351E-06 | -2.523 | |
| CONSTANT | 0 | 8.3376E-01 | 1.1850E-02 | 70.358 | |

16c. Third Iteration:

R-square = 0.8091  F = 25.44  .95 F = 3.16

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8879 | -4.7695E-04 | 9.3939E-05 | -5.077 | 1.734 |
| COM | -0.3576 | -9.0204E-06 | 3.1313E-06 | -2.881 | |
| PE | -0.3236 | -1.9392E-01 | 9.9872E-02 | -1.942 | |
| CONSTANT | 0 | 1.0267E+00 | 9.9963E-02 | 10.270 | |

16d. Fourth Iteration:

R-square = 0.8433  F = 22.87  .95 F = 2.96

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.9146 | -4.9129E-04 | 8.7910E-05 | -5.589 | 1.740 |
| COM | -0.2952 | -7.4471E-06 | 3.0320E-06 | -2.456 | |
| PE | -0.5134 | -3.0771E-01 | 1.1031E-01 | -2.789 | |
| PZBR | -0.2765 | -1.9186E-01 | 9.9706E-02 | -1.924 | |
| CONSTANT | 0 | 1.1487E+00 | 1.1275E-01 | 10.188 | |

16e. Fifth Iteration:

R-square = 0.8617  F = 19.94  .95 F = 2.85

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -1.0781 | -5.7910E-04 | 1.0425E-04 | -5.555 | 1.746 |
| COM | -0.3478 | -8.7725E-06 | 3.0734E-06 | -2.854 | |
| PE | -0.5964 | -3.5742E-01 | 1.1212E-01 | -3.188 | |
| PZBR | -0.3013 | -2.0906E-01 | 9.7267E-02 | -2.149 | |
| AR | -0.2058 | -1.2213E-01 | 8.3696E-02 | -1.459 | |
| CONSTANT | 0 | 1.3202E+00 | 1.6040E-01 | 8.231 | |

Figure 16. Selected Iterations of MC Forward Regression

Variables Regressed: P/NMCS, AD, AG, AR, AVLI, AX, AWMC, AWPC, AWP30, CG, COM, CR, CX, MM, MP, MR, PD, PE, POLI, PZBR

17a. Sixth Iteration:

R-square = 0.9946 F = 72.80 .95 F = 3.94

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.3766 | -2.0228E-04 | 4.3526E-05 | -4.647 | 1.943 |
| AD | -0.1644 | -3.5298E-06 | 1.1999E-06 | -2.942 | |
| AG | 0.4422 | 2.6204E-01 | 5.5743E-02 | 4.701 | |
| MR | 0.3007 | 2.2266E-01 | 9.6910E-02 | 2.298 | |
| PZBR | -0.6048 | -4.1960E-01 | 4.2578E-02 | -9.855 | |
| AX | -0.2528 | -2.6255E-01 | 8.0811E-02 | -3.249 | |
| AWMC | 0.5743 | 1.6318E-04 | 2.2699E-05 | 7.189 | |
| AWPC | -0.1999 | -5.7208E-05 | 3.2254E-05 | -1.774 | |
| AWP30 | -0.1903 | -1.2948E-04 | 4.9531E-05 | -2.614 | |
| CG | -0.8731 | -8.5401E-01 | 7.2232E-02 | -11.823 | |
| COM | -0.7303 | -1.8422E-05 | 2.8494E-06 | -6.465 | |
| CR | -0.7129 | -8.9743E-01 | 9.1886E-02 | -9.767 | |
| CX | -0.2666 | -2.6792E-01 | 6.7423E-02 | -3.974 | |
| MM | 0.3973 | 2.4103E-01 | 5.5208E-02 | 4.366 | |
| MP | -0.6031 | -3.4142E-01 | 4.2660E-02 | -8.003 | |
| CONSTANT | 0 | 2.5370E+00 | 1.7299E-01 | 14.665 | |

17b. Fifteenth Iteration:

R-square = 0.8573 F = 15.01 .95 F = 2.79

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.7406 | -3.9782E-04 | 7.6961E-05 | -5.169 | 1.753 |
| COM | -0.6150 | -1.5514E-05 | 3.9727E-06 | -3.905 | |
| CR | -0.4200 | -5.2865E-01 | 1.9630E-01 | -2.693 | |
| CG | -0.3322 | -3.2497E-01 | 1.3967E-01 | -2.327 | |
| MP | -0.2749 | -1.5560E-01 | 7.5350E-02 | -2.065 | |
| AWMC | 0.3777 | 1.0733E-04 | 5.0216E-05 | 2.137 | |
| CONSTANT | 0 | 1.5961E+00 | 2.5968E-01 | 6.147 | |

17c. Nineteenth Iteration:

R-square = 0.7691 F = 31.66 .95 F = 3.52

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.6475 | -3.4784E-04 | 7.1026E-05 | -4.897 | 1.724 |
| COM | -0.3336 | -8.4146E-06 | 3.3352E-06 | -2.523 | |
| CONSTANT | 0 | 8.3376E-01 | 1.1851E-02 | 70.352 | |

17d. Twentieth Iteration:

R-square = 0.6919 F = 44.91 .95 F = 4.35

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8318 | -4.4681E-04 | 6.6680E-05 | -6.701 | 1.725 |
| CONSTANT | 0 | 8.2267E-01 | 1.2394E-02 | 66.378 | |

Figure 17. Selected Iterations of MC Backward Regression

virtually all of the variability in the dependent variable, it is still expensive to maintain. Therefore, one should be willing to give up a part of this "explanatory power" in return for a model that "says almost as much" but with a lot fewer "words."

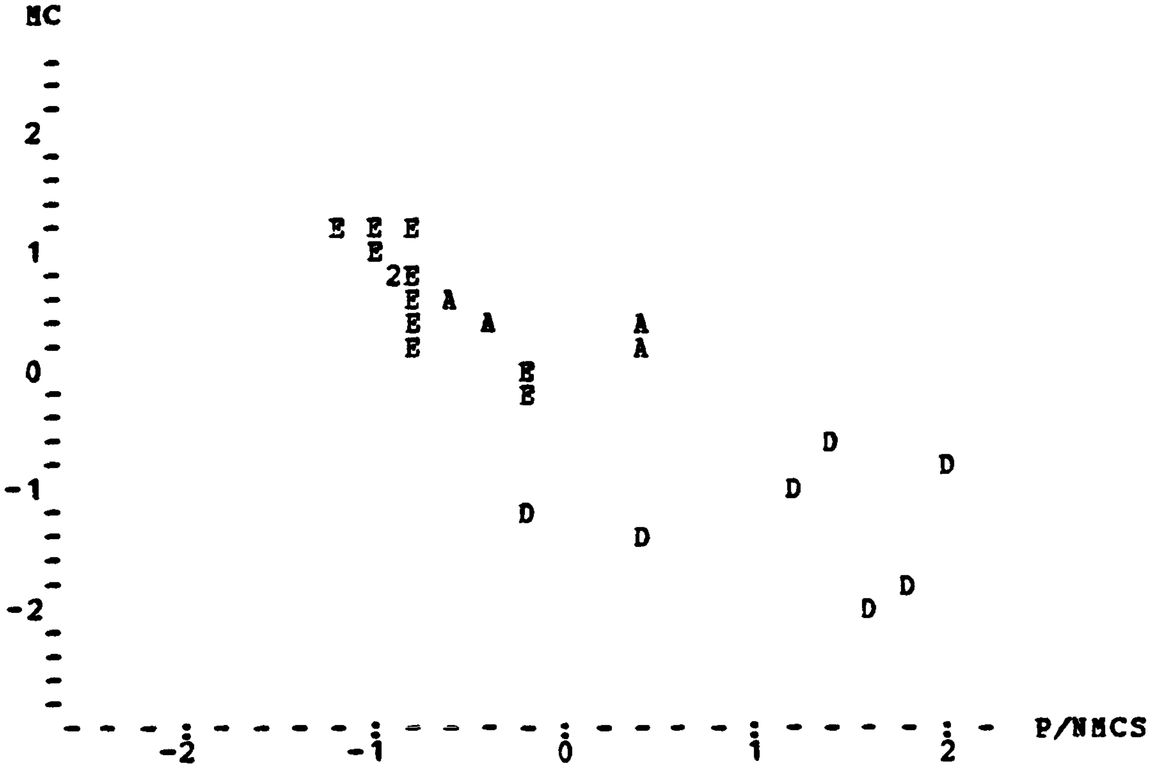
The important feature of the regressions in Figures 14 through 17 is that the same variable is the first one to enter the models in the forward regressions and is the last variable remaining in the models computed by the backward regressions. This variable is P/NMCS, which is the average daily number of PMCS and NMCS requisitions outstanding in the Supply System. The fact that the P/NMCS variable stands out is not entirely surprising, because this variable has the highest correlation with Mission Capability (-0.83). This high correlation was expected because, as was pointed out in Section II, this variable is the only variable in the data base that can be directly associated with an aircraft in PMC or NMC status. In view of these results, the author decided to investigate the relationship between MC and P/NMCS further.

## F. ANALYSIS OF SUPPLY REQUISITIONS

### 1. Relationship Between Mission Capability and the P/NMCS Variable

Figure 18 shows the results of the regression of MC on the variable P/NMCS. It is apparent from the scatter plot (Figure 18a) alone that there is a strong relationship between these variables. As expected, the data from ship CV4 ("D") is plotted at the lower end of the "curve." If one examines just the data from CV4, there does not appear to be any relationship. In fact, the correlation between MC and P/NMCS for the CV4 data is a poor -0.05 (from Table 15). It must be recalled, however, that this ship experienced poor Supply performance and was characterized by

18a. Scatter Plot of 22 Standardized Values of MC vs. P/NMCS




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| MC | 0.0 | 1.000 | dimensionless | A: | CV1 |
| P/NMCS | 162.64 | 92.099 | # of requisitions | D: | CV4 |
| | | | | E: | CV5 |

18b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.8318 | -4.4682E-04 | 6.6676E-05 | -6.701 | 1.725 |
| CONSTANT | 0 | 8.2267E-01 | 1.2393E-02 | 66.382 | |

18c. R-square Values:

UNADJUSTED: 0.6919 ADJUSTED: 0.6765

18d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 3.55620E-02 | 1 | 3.55620E-02 | | |
| RESIDUALS | 1.58379E-02 | 20 | 7.91897E-04 | 44.91 | 4.35 |
| TOTAL | 5.13999E-02 | 21 | 2.44762E-03 | | |

Figure 18.

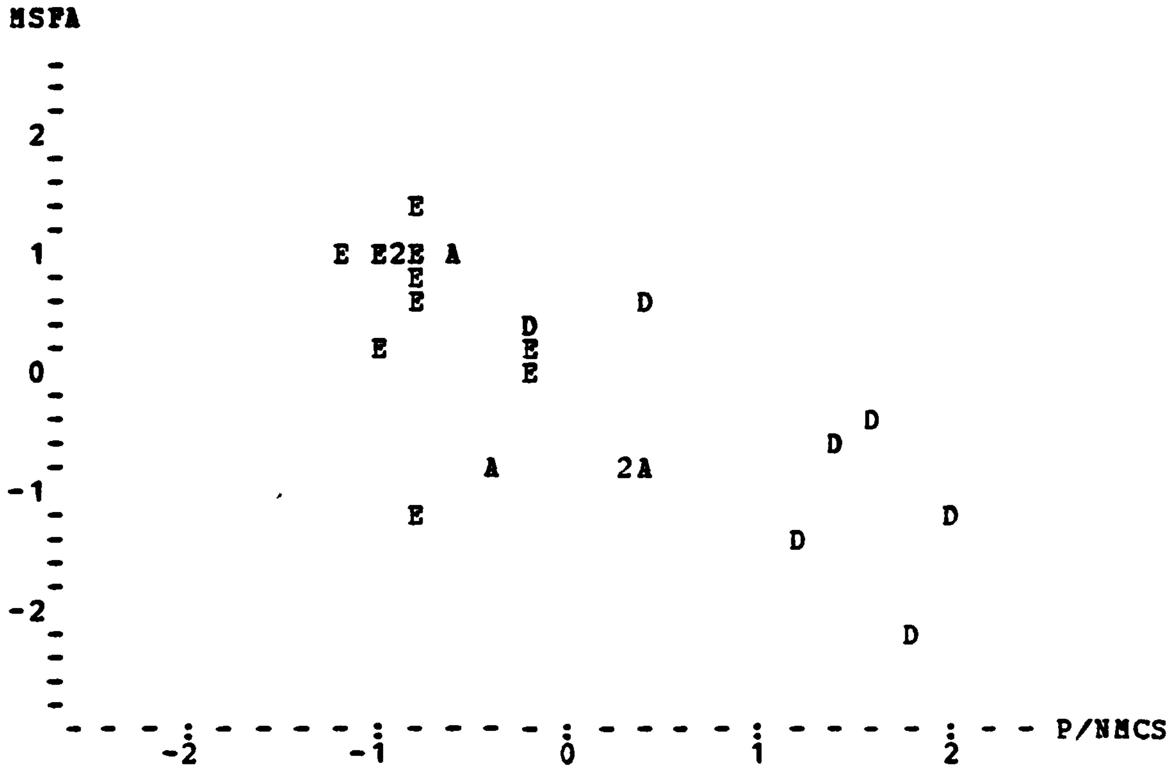
Analysis of the Relationship Between MC and P/NMCS

very high values of P/NMCS that were subject to large variations. This fact is confirmed by the mean value and standard deviation of the CV4 P/NMCS data listed in Table 7 (271.143 and 73.1538, respectively). These values are respectively 110 and 31 units greater than the second largest mean and standard deviation observed. If the three ships are treated as a reasonably homogeneous group, which is the assumption here, the CV4 data fits quite nicely to the pattern indicated by Figure 18a, and the analysis appears to be valid.

The regression results in Figures 18b, 18c, and 18d speak fairly well for themselves, and the linear model appears to be a significant representation of the relationship between MC and P/NMCS. The only comment here concerns the magnitude of the regression coefficient for the P/NMCS variable. This value is so small because the P/NMCS variable is several orders of magnitude larger than the MC variable, which ranges in value only from 0 to 1.

It is interesting to note here that although there was no indication of a relationship between the MSFA Support Factor and MC, there does appear to be a relationship between this Support Factor and the P/NMCS variable. An analysis of this is presented in Figure 19, where it is seen that a significant linear relationship exists. It may be recalled that in the analysis of MC and MSFA in Figure 7a, the data were observed to plot in distinguishable clusters. In Figure 19a, this clustering is not so obvious. This creates somewhat of a paradox among the relationships examined to this point. First, it was observed that MC and MSFA exhibited a statistically significant linear relationship, but this was invalidated by the clustering of the individual ship data sets. Second, P/NMCS was

19a. Scatter Plot of 22 Standardized Values of MSFA vs. P/NMCS




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| MSFA | 0.78630 | 0.04443 | dimensionless | A: | CV1 |
| P/NMCS | 162.64 | 92.099 | # of requisitions | D: | CV4 |
| | | | | E: | CV5 |

19b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| P/NMCS | -0.7396 | -3.5683E-04 | 7.2603E-05 | -4.915 | 1.725 |
| CONSTANT | 0 | 8.4433E-01 | 1.3495E-02 | 62.568 | |

19c. R-square Values:

UNADJUSTED: 0.5471 ADJUSTED: 0.5244

19d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 2.26803E-02 | 1 | 2.26803E-02 | | |
| RESIDUALS | 1.87790E-02 | 20 | 9.38948E-04 | 24.16 | 4.35 |
| TOTAL | 4.14593E-02 | 21 | 1.97425E-03 | | |

Figure 19.

Analysis of the Relationship Between MSFA and P/NMCS

observed to have a strong linear relationship with MC. Now it has been observed that P/NMCS has a statistically significant relationship with MSFA, and the clustering of data is no longer apparent. This is not acutally the problem that it appears to be, because the two relationships that were found to be significant (i.e., MC-P/NMCS and P/NMCS-MSFA) do not necessarily imply that the third relationship (MC-MSFA) must be significant. This situation lends itself to the observations that follow.

It has been seen that the P/NMCS variable is more associated with MC than any of the other performance variables. Second, the linear relationship between these variables is statistically significant. Third, the P/NMCS variable is the only variable that can be directly associated to aircraft readiness. Therefore, if P/NMCS is used as a substitute measure of readiness, then the MSFA Support Factor does appear to provide a related measure of Supply performance.

2. Relationship Between the P/NMCS Variable and the Performance Variables

Because the P/NMCS variable is so strongly related to aircraft readiness, it would be desirable to investigate the relationship of P/NMCS with the other performance variables. This analysis was performed by the forward and backward regressions shown in Figures 20 and 21. Again, several of the regression iterations have been omitted.

In the forward regression of Figure 20, it can be seen that in the first three iterations (Figures 20a, 20b, and 20c) the variables PX, AR, and PE enter the model in the respective order given. It is interesting to note that in the linear models, the negative signs of the regression coefficients agree with the intuitive associations of the variables, i.e., if POOL Effectiveness, AVCAL Range, or POOL Depth

Variables Regressed: AG, AN, AR, AX, AWMC, AWPC, AWP30, AWP60, CN, COM, CR, CX, MM, MP, MR, PE, PR, PX, PZBR

20a. First Iteration:

R-square = 0.6255 F = 33.40 .95 F = 4.35

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PX | -0.7909 | -6.3368E+02 | 1.0965E+02 | -5.779 | 1.725 |
| CONSTANT | 0 | 7.0040E+02 | 9.3860E+01 | 7.462 | |

20b. Second Iteration:

R-square = 0.7334 F = 26.14 .95 F = 3.52

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PX | -0.5945 | -4.7635E+02 | 1.1056E+02 | -4.309 | 1.729 |
| AR | -0.3828 | -4.2299E+02 | 1.5248E+02 | -2.774 | |
| CONSTANT | 0 | 9.3776E+02 | 1.1799E+02 | 7.948 | |

20c. Third Iteration:

R-square = 0.7971 F = 23.57 .95 F = 3.16

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PX | -0.2961 | -2.3727E+02 | 1.4125E+02 | -1.680 | 1.734 |
| AR | -0.3646 | -4.0288E+02 | 1.3695E+02 | -2.942 | |
| PE | -0.3982 | -4.4424E+02 | 1.8701E+02 | -2.375 | |
| CONSTANT | 0 | 1.1066E+03 | 1.2742E+02 | 8.684 | |

20d. Fourth Iteration:

R-square = 0.8403 F = 22.38 .95 F = 2.96

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PX | -0.1098 | -8.7961E+01 | 1.4643E+02 | -0.601 | 1.740 |
| AR | -0.2226 | -2.4599E+02 | 1.4473E+02 | -1.700 | |
| PE | -0.4534 | -5.0588E+02 | 1.7304E+02 | -2.923 | |
| MR | 0.3252 | 4.4834E+02 | 2.0864E+02 | 2.149 | |
| CONSTANT | 0 | 5.8614E+02 | 2.6865E+02 | 2.182 | |

Figure 20. Selected Iterations of P/NMCS Forward Regression

Variables Regressed: AG, AN, AR, AX, AWMC, AWPC, AWP30, AWP60, CN, COM, CR, CX, MM, MP, MR, PE, PR, PX, PZBR

21a. Sixteenth Iteration:

R-square = 0.9027  F = 39.41  .95 F = 2.96

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| AG | -0.6244 | -6.8886E+02 | 1.8638E+02 | -3.696 | 1.740 |
| AN | 0.3965 | 5.1619E+02 | 2.1310E+02 | 2.422 | |
| MR | 0.3551 | 4.8955E+02 | 1.3005E+02 | 3.764 | |
| PE | -0.6142 | -6.8527E+02 | 9.8475E+01 | -6.959 | |
| CONSTANT | 0 | 4.5436E+02 | 1.9219E+02 | 2.364 | |

21b. Seventeenth Iteration:

R-square = 0.8690  F = 39.82  .95 F = 3.16

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| AG | -0.2689 | -2.9662E+02 | 1.0402E+02 | -2.852 | 1.734 |
| PE | -0.6261 | -6.9852E+02 | 1.1082E+02 | -6.303 | |
| MR | 0.3698 | 5.0984E+02 | 1.4628E+02 | 3.485 | |
| CONSTANT | 0 | 6.0154E+02 | 2.0551E+02 | 2.927 | |

21c. Eighteenth Iteration:

R-square = 0.8098  F = 40.48  .95 F = 3.52

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| MR | 0.4981 | 6.8674E+02 | 1.5536E+02 | 4.420 | 1.724 |
| PE | -0.5544 | -6.1849E+02 | 1.2573E+02 | -4.919 | |
| CONSTANT | 0 | 2.2956E+02 | 1.8624E+02 | 1.233 | |

21d. Nineteenth Iteration:

R-square = 0.6143  F = 31.87  .95 F = 4.35

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PE | -0.7839 | -8.7454E+02 | 1.5491E+02 | -5.645 | 1.725 |
| CONSTANT | 0 | 9.2905E+02 | 1.3633E+02 | 6.815 | |

Figure 21.

Selected Iterations of P/NMCS Backward Regression

increase, the number of requisitions outstanding decreases. This is logical because if there is more RFI material on hand (measured by AR and PX) and the ratio of demands issued from the Rotatable Pool (measured by PE) is high, one would naturally expect to order fewer parts and components from off-ship sources.

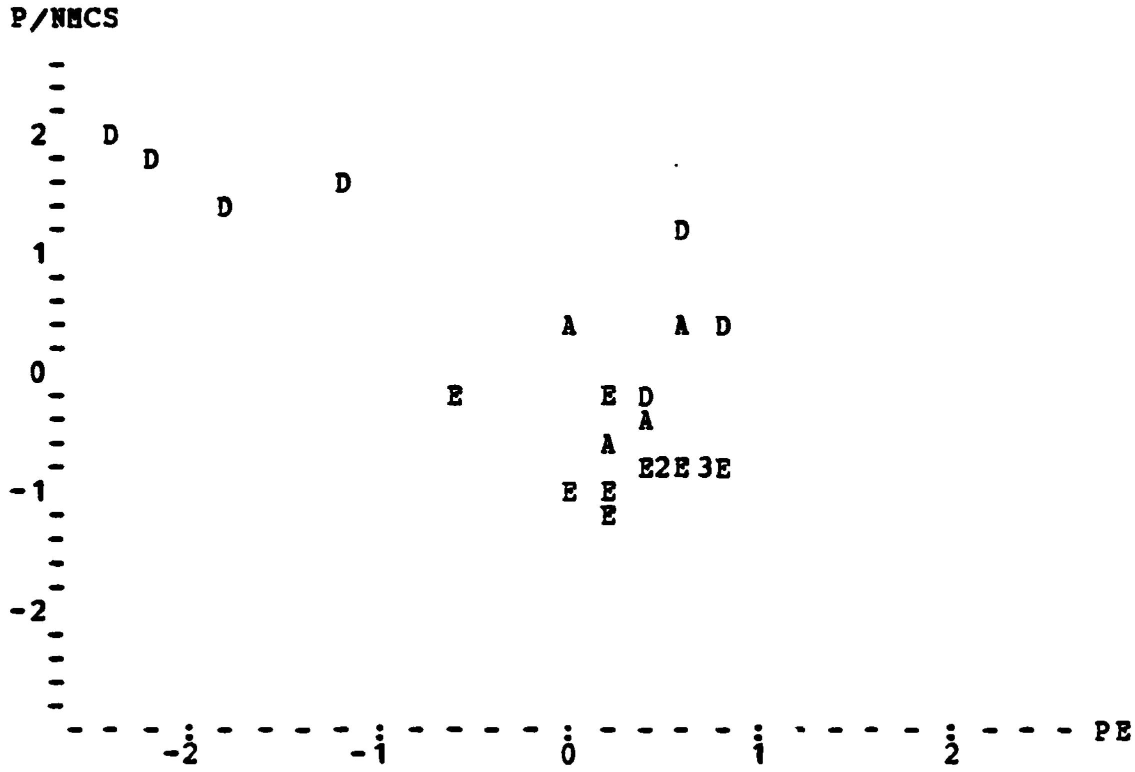
The three-variable model of Figure 20c does have multicolinearity in it because of the high correlation between PE and PX (0.77). This becomes more obvious in Figure 20d, when the Repair Rate (MR) enters the model. The MR variable has a high correlation with P/NMCS (0.75), but is also correlated with PX (-0.67). The Repair Rate, however, has been determined to be a poor indicator of performance, and the remaining iterations of the forward regression have been disregarded.

In the backward regression of Figure 21, the MR variable does not exit the model until the last iteration (Figure 21d), but it can still be seen from the iteration sequence that performance variables from both the Rotatable Pool and AVCAL inventory groups have significant relationships with the P/NMCS variable. It may be recalled that performance variables from these inventory groups were also found to be significantly related to Mission Capability. Several of these relationships are examined more closely in the subsections which follow.

### 3. Relationship Between the P/NMCS Variable and Rotatable Pool Performance Indicators

Figures 22 and 23 show the analyses of P/NMCS with the variables PE and PX, respectively. Both analyses indicate significant linear relationships with the P/NMCS variable, and, with the exception of the magnitudes of the regression coefficients, appear to be nearly identical. This is not surprising because of the high correlation between PE and

22a. Scatter Plot of 22 Standardized Values of P/NMCS vs. PE




| | MEAN | STD. DEV. | UNITS | |
|---|---|---|---|---|
| P/NMCS | 162.64 | 92.099 | # of requisitions | A: CV1 |
| PE | 0.87636 | 0.082551 | dimensionless | D: CV4 |
| | | | | E: CV5 |

22b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PE | -0.7838 | -8.7450E+02 | 1.5491E+02 | -5.645 | 1.725 |
| CONSTANT | 0 | 9.2902E+02 | 1.3633E+02 | 6.814 | |

22c. R-square Values:

UNADJUSTED: 0.6144 ADJUSTED: 0.5951

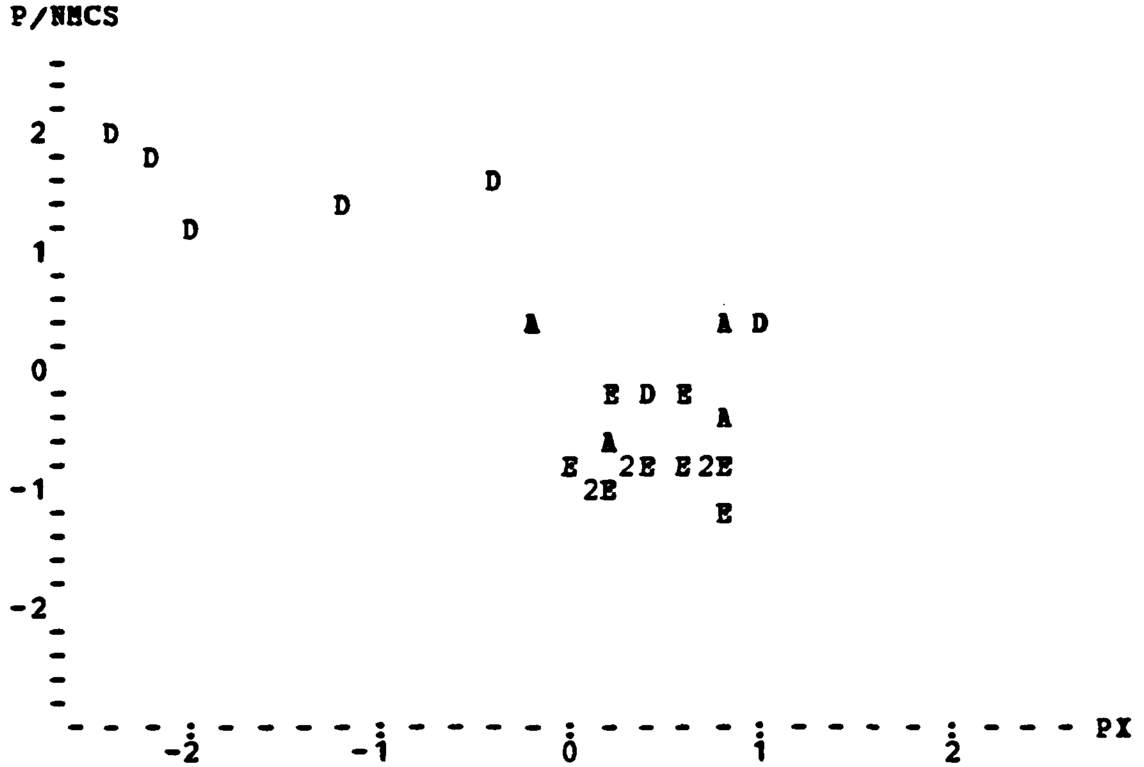
22d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 1.09443E+05 | 1 | 1.09443E+05 | | |
| RESIDUALS | 6.86836E+04 | 20 | 3.43418E+03 | 31.87 | 4.35 |
| TOTAL | 1.78127E+05 | 21 | 8.48222E+03 | | |

Figure 22.

Analysis of the Relationship Between P/NMCS and PE

23a. Scatter Plot of 22 Standardized Values of P/NMCS vs. PX




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| P/NMCS | 162.64 | 92.099 | # of requisitions | A: | CV1 |
| PX | 0.84864 | 0.11494 | dimensionless | D: | CV4 |
| | | | | E: | CV5 |

23b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PX | -0.7909 | -6.3368E+02 | 1.0965E+02 | -5.779 | 1.725 |
| CONSTANT | 0 | 7.0040E+02 | 9.3860E+01 | 7.462 | |

23c. R-square Values:

UNADJUSTED: 0.6255 ADJUSTED: 0.6068

23d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 1.11414E+05 | 1 | 1.11414E+05 | | |
| RESIDUALS | 6.67123E+04 | 20 | 3.33562E+03 | 33.40 | 4.35 |
| TOTAL | 1.78127E+05 | 21 | 8.48222E+03 | | |

Figure 23.

Analysis of the Relationship Between P/NMCS and PX

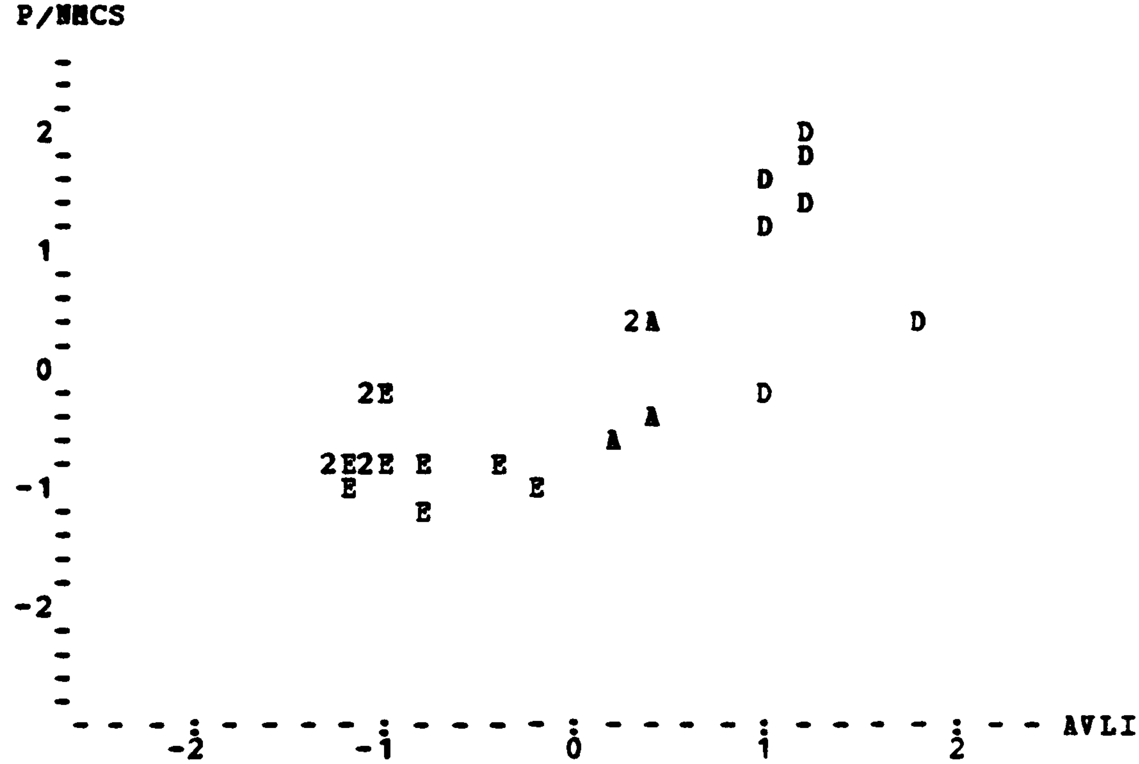
PX (0.77). The item of interest here is that P/NMCS appears to be strongly influenced by Rotatable Pool transactions.

4. Relationship Between the P/NMCS Variable and Number of AVCAL Line Items

Figure 24 shows the relationship of P/NMCS with AVLI, the number of AVCAL line items. This analysis has been included here because the AVLI variable is highly correlated with both P/NMCS (0.81) and MC (-0.78). The number-of-line-items variables for the three inventory groups have yet to be discussed in this report, and they will not be examined in detail. The reason for this can be seen in the scatter plot of Figure 24a. There appears to be a strong relationship between P/NMCS and AVLI. This is supported by the regression results in Figures 24b, 24c, and 24d. However, the relationship that is implied is contrary to logic. Collectively, the data indicate that larger inventories are associated with greater numbers of off-ship requisitions. A closer look at Figure 24a once again reveals a clustering effect, and each set of data from the three ships may be easily segregated into groups that characterize the relative size of each ship's inventory.

Inspection of the correlation matrix of Table 11 in Appendix B reveals several high correlations between the number-of-line-items variables and the other performance variables. Because of the disjoint nature of the ship's inventories and the misleading associations that are indicated, no attempt was made at analyzing or explaining these relationships.

24a. Scatter Plot of 22 Standardized Values of P/NMCS vs. AVLI




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| P/NMCS | 162.64 | 92.099 | # of requisitions | A: | CV1 |
| AVLI | 42541 | 5557.5 | # of line items | D: | CV4 |
| | | | | E: | CV5 |

24b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| AVLI | 0.8060 | 1.3356E-02 | 2.1937E-03 | 6.089 | 1.725 |
| CONSTANT | 0 | -4.0556E+02 | 9.4077E+01 | -4.311 | |

24c. R-square Values:

UNADJUSTED: 0.6496 ADJUSTED: 0.6320

24d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 1.15704E+05 | 1 | 1.15704E+05 | | |
| RESIDUALS | 6.24226E+04 | 20 | 3.12113E+03 | 37.07 | 4.35 |
| TOTAL | 1.78127E+05 | 21 | 8.48222E+03 | | |

Figure 24.

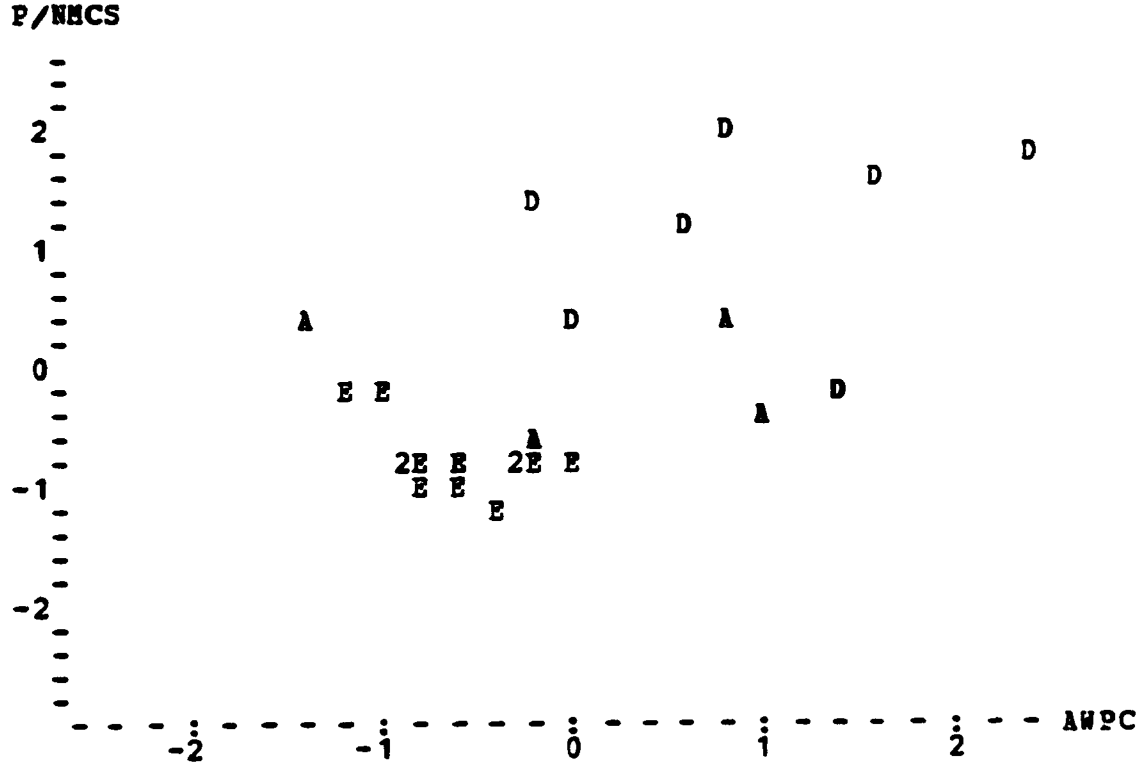
Analysis of the Relationship Between P/NMCS and AVLI

### 5. Relationship Between the P/NMCS Variable and the Number of Components Awaiting Parts or Maintenance

The correlation matrix (Table 11) of the pooled data from ships CV1, CV4, and CV5 indicates two additional variables that have relatively large correlations with P/NMCS. These were not singled out by the forward and backward regressions. These variables are the Number of Components Awaiting Parts (AWPC) and the Number of Components Awaiting Maintenance (AWMC), which have correlation coefficients of 0.60 and 0.70, respectively, with the P/NMCS variable. The analysis of the relationship of P/NMCS with AWPC is shown in Figure 25, and the corresponding analysis with AWMC is shown in Figure 26.

The analysis results in Figure 25 are very interesting, because they show a good example of what can happen if an analyst puts too much faith in his assumptions; in this instance, it is the assumption that the pooling of data maintains a homogeneous group. At first glance, there appears to be a statistically significant relationship, as measured by the t-statistic for AWPC and the F-statistic for the model. Both the regression model and the scatter plot indicate a positive linear relationship between P/NMCS and AWPC. However, when one looks at the P/NMCS-AWPC correlations of the individual ships CV1, CV4, and CV5, it is seen that they are all <u>negative</u> (-0.30, -0.80, and -0.62, respectively). Pooling the data has concealed the true relationship. Separate analyses of these data have not been conducted because of the small number of observations on each ship. Even if a large number of observations were available for analyses, it is not certain that a relationship between P/NMCS and AWPC could be developed. There is no intuitive reason to suggest that there is any relationship between these variables.

25a. Scatter Plot of 22 Standardized Values of P/NMCS vs. AWPC




| | MEAN | STD. DEV. | UNITS | |
|---|---|---|---|---|
| P/NMCS | 162.64 | 92.099 | # of requisitions | A: CV1 |
| AWPC | 399.73 | 172.88 | # of components | D: CV4 |
| | | | | E: CV5 |

25b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| AWPC | 0.5987 | 3.1895E-01 | 9.5418E-02 | 3.343 | 1.725 |
| CONSTANT | 0 | 3.5145E+01 | 4.1406E+01 | 0.849 | |

25c. R-square Values:

UNADJUSTED: 0.3584 ADJUSTED: 0.3263

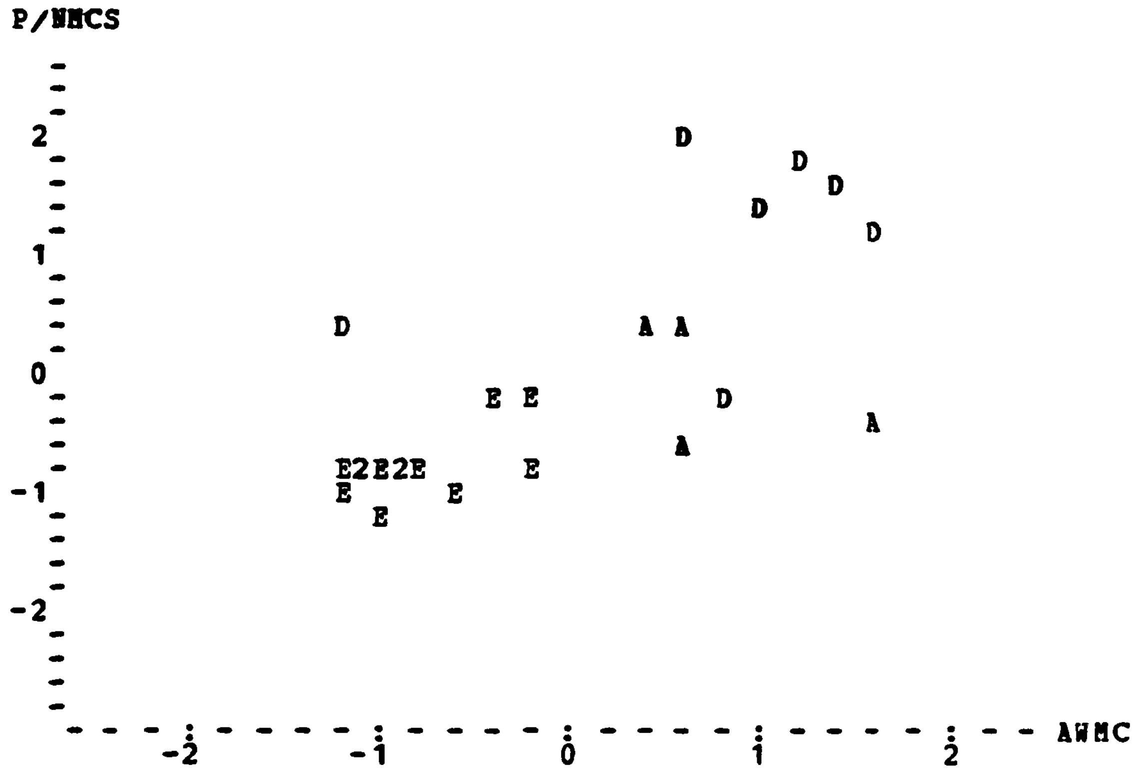
25d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 6.38447E+04 | 1 | 6.38447E+04 | | |
| RESIDUALS | 1.14282E+05 | 20 | 5.71409E+03 | 11.17 | 4.35 |
| TOTAL | 1.78127E+05 | 21 | 8.48222E+03 | | |

Figure 25.

Analysis of the Relationship Between P/NMCS and AWPC

26a. Scatter Plot of 22 Standardized Values of P/NMCS vs. AWMC




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| P/NMCS | 162.64 | 92.099 | # of requisitions | A: | CV1 |
| AWMC | 225.45 | 174.12 | # of components | D: | CV4 |
| | | | | E: | CV5 |

26b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| AWMC | 0.7008 | 3.7069E-01 | 8.4375E-02 | 4.393 | 1.725 |
| CONSTANT | 0 | 7.9063E+01 | 2.3830E+01 | 3.318 | |

26c. R-square Values:

UNADJUSTED: 0.4911 ADJUSTED: 0.4657

26d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 8.74811E+04 | 1 | 8.74811E+04 | | |
| RESIDUALS | 9.06456E+04 | 20 | 4.53228E+03 | 19.30 | 4.35 |
| TOTAL | 1.78127E+05 | 21 | 8.48222E+03 | | |

Figure 26.

Analysis of the Relationship Between P/NMCS and AWMC

The analysis of P/NMCS with AWMC in Figure 26 is similar. In this analysis, the individual P/NMCS-AWMC correlations of ships CV1, CV2, and CV5 are -0.56, 0.40, and 0.67, respectively. The contrasting positive and negative signs on the correlation coefficients confuse the issue here, but it appears that there exists the same type of situation that was seen in the previous analysis. This idea can be supported when one notices that at least one of the observations from ship CV4 plotted in Figure 26a appears to be an outlier which, upon removal, would reverse the sign on the correlation of the CV4 data.

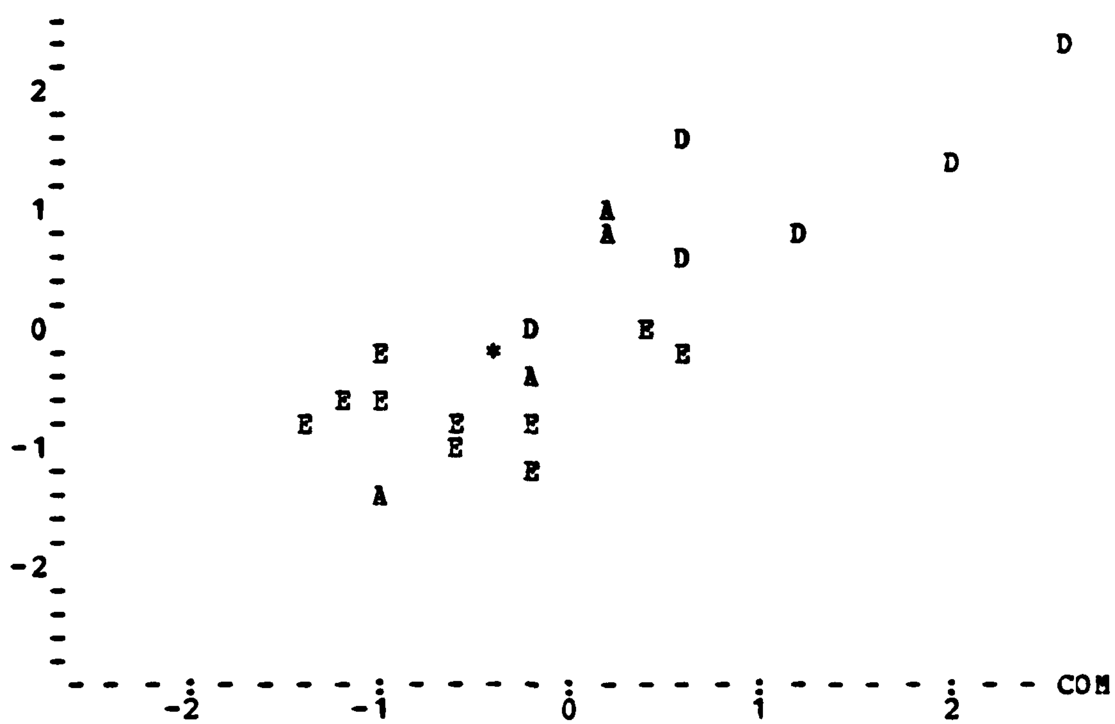
## G. ADDITIONAL PERFORMANCE VARIABLE RELATIONSHIPS

The correlation matrices of Appendix B suggest many different associations between variables that warrant further investigation. This report cannot possibly address them all; however, this subsection presents a few final observations and analyses that point out interesting or surprising relationships, or clarify earlier statements.

### 1. Relationship Between the Number of Components Awaiting Parts or Maintenance and the Number of Components Inducted

Figures 27 and 28 show the respective analyses of the relationship between the variables AWPC and AWMC, and the number of components inducted (COM). Both analyses indicate that the number of repairable components which are in repair queues, or are waiting for repair parts at the end of a month, are directly and positively related to the number of components that were inducted during the month. The surprising result here is that the relationship between AWPC and COM appears to be much stronger than the relationship between AWMC and COM. One would normally expect this situation to be reversed. This result supports the statements made

27a. Scatter Plot of 22 Standardized Values of AWPC vs. COM




| | MEAN | STD.DEV. | UNITS |
|---|---|---|---|
| AWPC | 399.73 | 172.88 | # of components |
| COM | 3231.5 | 1961.4 | # of components |

A: CV1
D: CV4
E: CV5
*: D,E

27b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| COM | 0.8315 | 7.3285E-02 | 1.0950E-02 | 6.693 | 1.725 |
| CONSTANT | 0 | 1.6290E+02 | 4.1139E+01 | 3.960 | |

27c. R-square Values:

UNADJUSTED: 0.6913 ADJUSTED: 0.6759

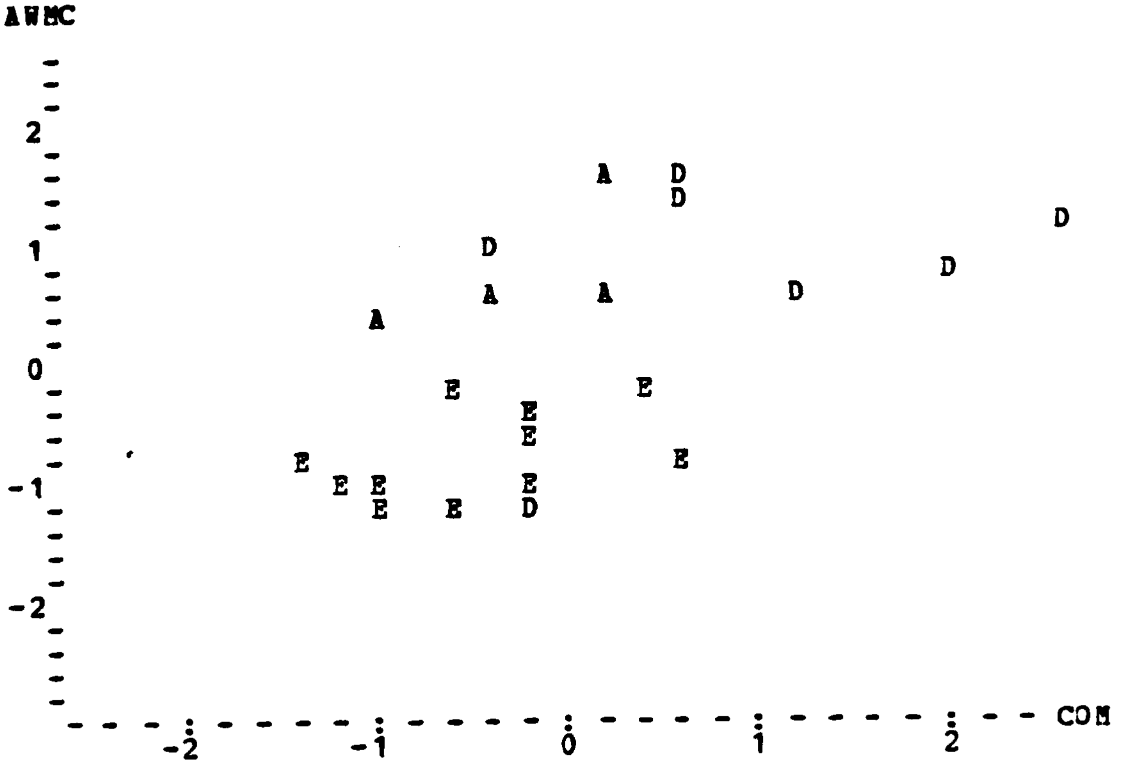
27d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 4.33876E+05 | 1 | 4.33876E+05 | | |
| RESIDUALS | 1.93732E+05 | 20 | 9.68658E+03 | 44.79 | 4.35 |
| TOTAL | 6.27608E+05 | 21 | 2.98861E+04 | | |

Figure 27.

Analysis of the Relationship Between AWPC and COM

28a. Scatter Plot of 22 Standardized Values of AWMC vs. COM




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| AWMC | 225.45 | 174.12 | # of components | A: | CV1 |
| COM | 3231.5 | 1961.4 | # of components | D: | CV4 |
| | | | | E: | CV5 |

28b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| COM | 0.5802 | 5.1508E-02 | 1.6167E-02 | 3.186 | 1.725 |
| CONSTANT | 0 | 5.9004E+01 | 6.0739E+01 | 0.971 | |

28c. R-square Values:

UNADJUSTED: 0.3367 ADJUSTED: 0.3035

28d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 2.14335E+05 | 1 | 2.14335E+05 | | |
| RESIDUALS | 4.22304E+05 | 20 | 2.11152E+04 | 10.15 | 4.35 |
| TOTAL | 6.36639E+05 | 21 | 3.03161E+04 | | |

Figure 28.

Analysis of the Relationship Between AWMC and COM

earlier concerning the usefulness of EOM-Snapshot variables such as AWMC. This is further emphasized by the next set of analyses.

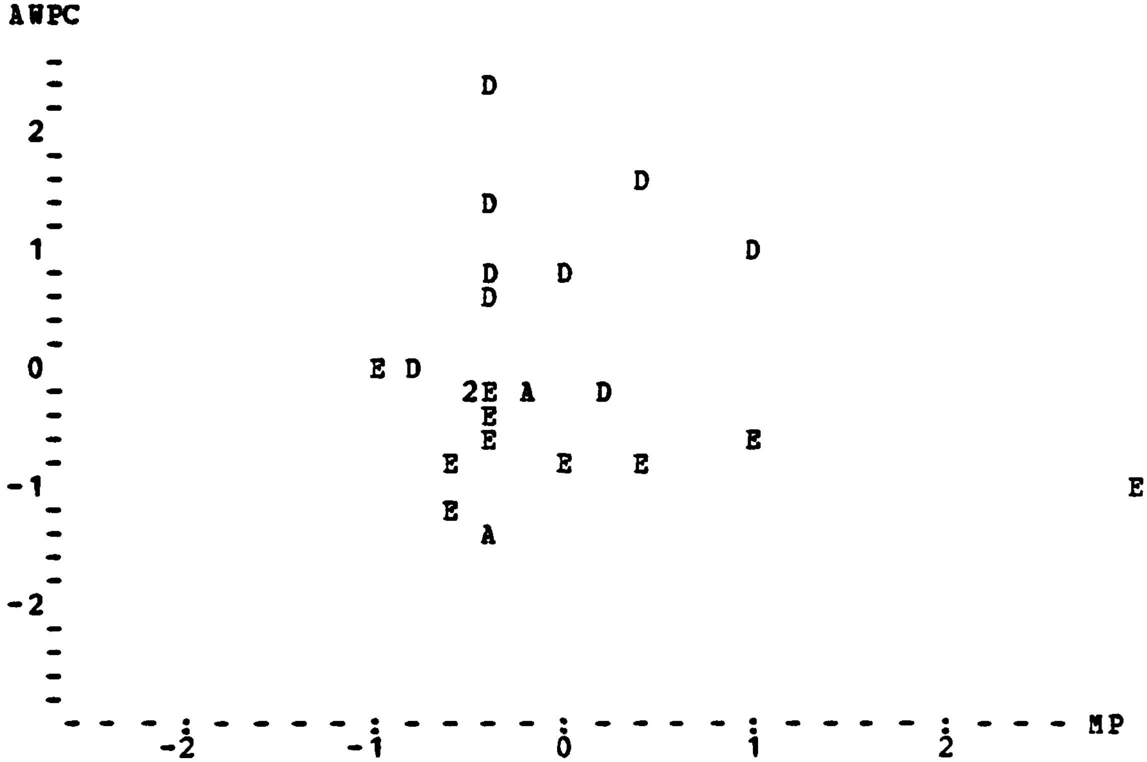
2. Assessment of End-of-the-Month-Snapshot Variables

In the discussion of EOM-Snapshot variables earlier in this section, it was pointed out that these singular-type variables might possibly be related to variables measured over an entire month if a cause-and-effect relationship was assumed. Figures 29 and 30 show that this is not the case for the AWPC and AWMC variables, respectively. In the analyses, the AWPC and AWMC variables were regressed on the respective rate variables MP and MM. The results are quite obvious. There is nothing to suggest that a high AWP rate or a high AWM rate during a month will create a correspondingly large number of respective AWP or AWM components on the last day of that month. This is characteristic of the problem with EOM-Snapshot variables. The fact that a small number of components in AWP or AWM status is observed on the last day of a month does not necessarily mean that there was a small number of components in that status on the previous day, or the day before that.

3. Analysis of the POOL Zero Balance Rate

Figures 31 and 32 are regression analyses involving the POOL Zero Balance Rate (PZBR). In Figure 31, the POOL Effectiveness variable has been regressed on PZBR. Although many of the data plotted in Figure 31a are tightly grouped, there are enough values in the lower right area of the graph to suggest a definite relationship. This is confirmed by the regression results of Figures 31b, 31c, and 31d. It will be recalled that PZBR is the average daily ratio of POOL line items with zero RFI material on hand to total POOL line items. Thus, the regression results

29a. Scatter Plot of 22 Standardized Values of AWPC vs. MP




| | MEAN | STD. DEV. | UNITS | | |
|---|---|---|---|---|---|
| AWPC | 399.73 | 172.88 | # of components | A: | CV1 |
| MP | 0.14773 | 0.087392 | dimensionless | D: | CV4 |
| | | | | E: | CV5 |

29b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| MP | -0.1069 | -2.1145E+02 | 4.3980E+02 | -0.481 | 1.725 |
| CONSTANT | 0 | 4.3096E+02 | 7.5041E+01 | 5.743 | |

29c. R-square Values:

UNADJUSTED: 0.0114 ADJUSTED: 0.0

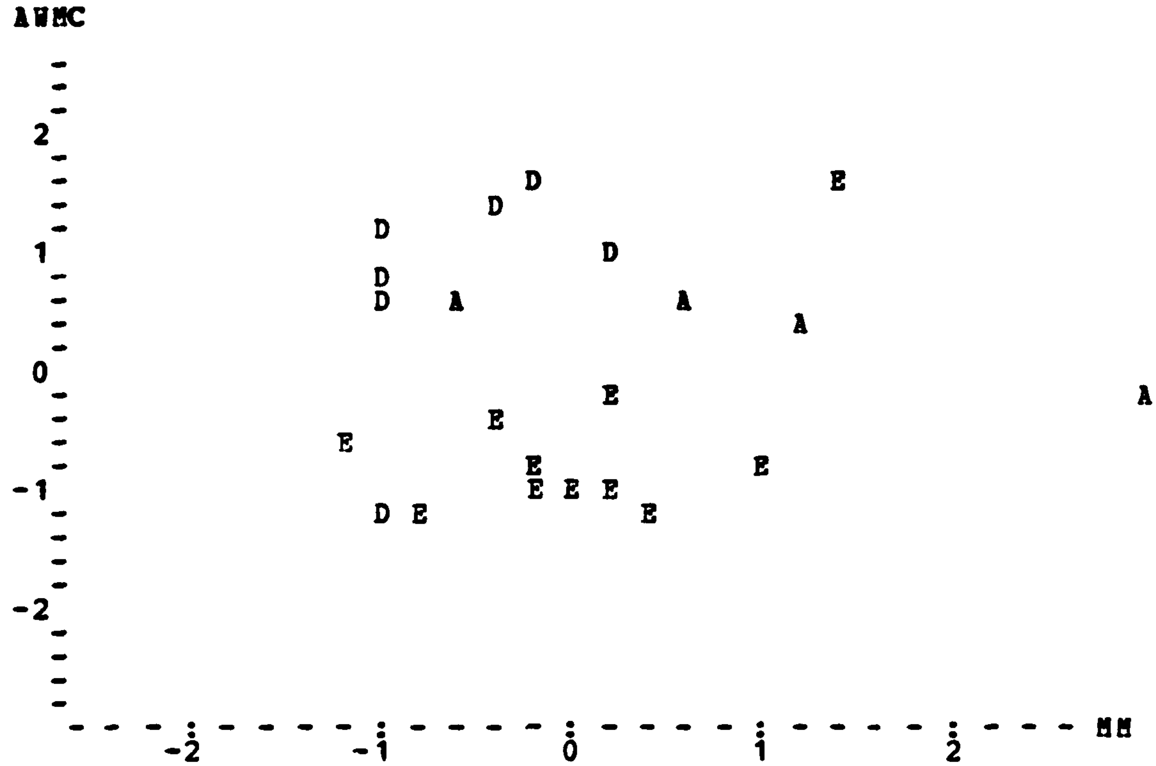
29d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 7.17106E+03 | 1 | 7.17106E+03 | | |
| RESIDUALS | 6.20437E+05 | 20 | 3.10218E+04 | 0.23 | 3.54 |
| TOTAL | 6.27608E+05 | 21 | 2.98861E+04 | | |

Figure 29.

Analysis of the Relationship Between AWPC and MP

30a. Scatter Plot of 22 Standardized Values of AWMC vs. MM




| | MEAN | STD.DEV. | UNITS | |
|---|---|---|---|---|
| AWMC | 225.45 | 174.12 | # of components | A: CV1 |
| MM | 0.13864 | 0.081550 | dimensionless | D: CV4 |
| | | | | E: CV5 |

30b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| MM | 0.0289 | 6.1676E+01 | 4.7722E+02 | 0.129 | 1.725 |
| CONSTANT | 0 | 2.1690E+02 | 7.6307E+01 | 2.843 | |

30c. R-square Values:

UNADJUSTED: 0.0008 ADJUSTED: 0.0

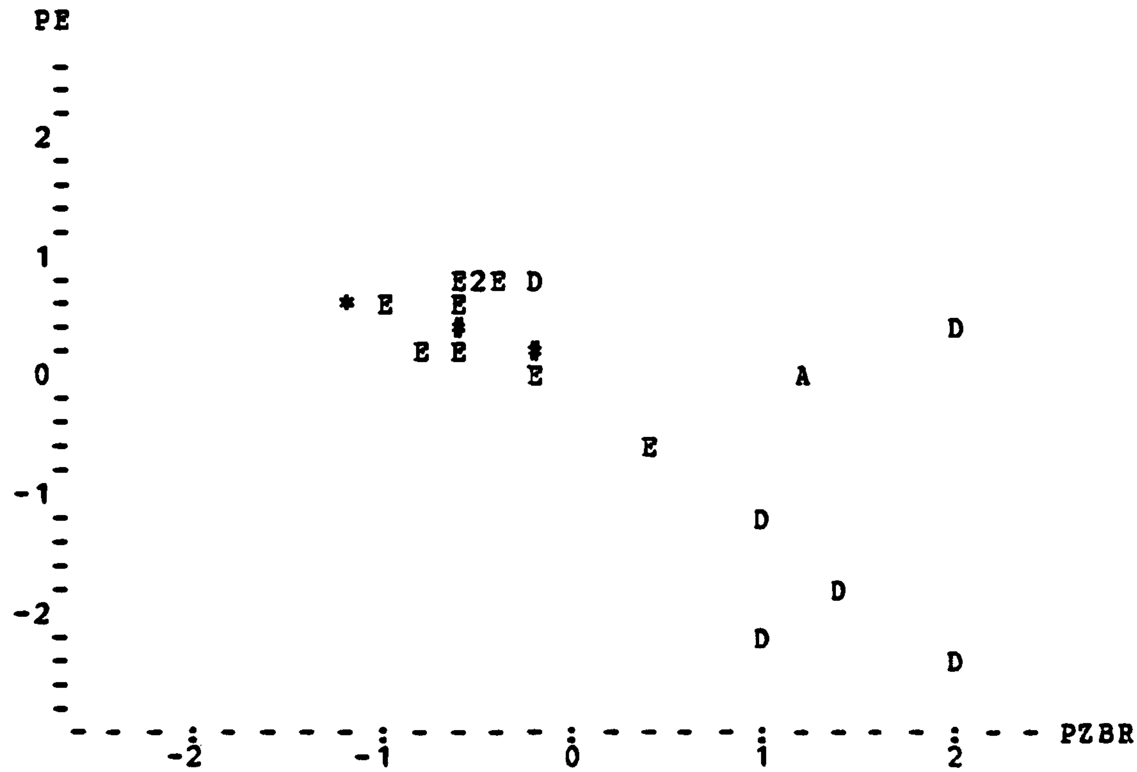
30d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 5.312500E+02 | 1 | 5.312500E+02 | | |
| RESIDUALS | 6.361080E+05 | 20 | 3.180540E+04 | 0.02 | 4.35 |
| TOTAL | 6.366390E+05 | 21 | 3.031610E+04 | | |

Figure 30.

Analysis of the Relationship Between AWMC and MM

31a. Scatter Plot of 22 Standardized Values of PE vs. PZBR




| | MEAN | STD. DEV. | UNITS |
|---|---|---|---|
| PE | 0.87636 | 0.082551 | dimensionless |
| PZBR | 0.13091 | 0.071308 | dimensionless |

| | |
|---|---|
| A: | CV1 |
| D: | CV4 |
| E: | CV5 |
| *: | A,D |
| #: | A,E |

31b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PZBR | -0.7202 | -8.3373E-01 | 1.7960E-01 | -4.642 | 1.725 |
| CONSTANT | 0 | 9.8551E-01 | 2.6633E-02 | 37.003 | |

31c. R-square Values:

UNADJUSTED: 0.5187 ADJUSTED: 0.4946

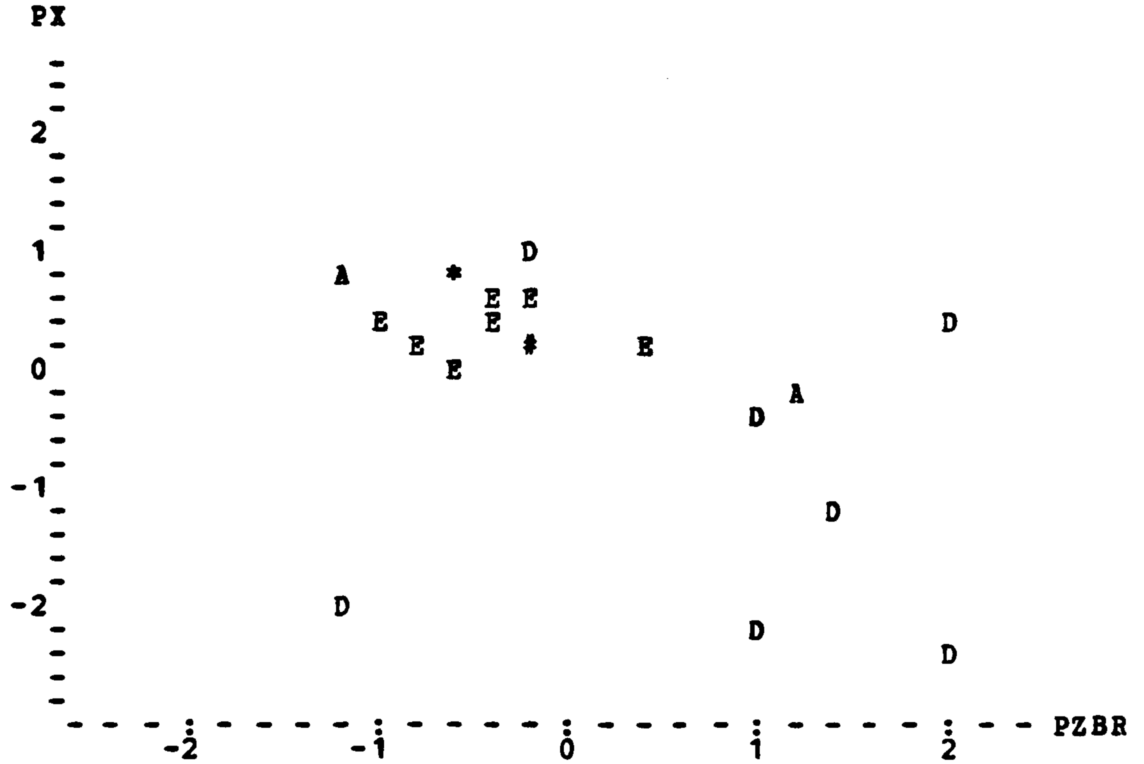
31d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 7.42251E-02 | 1 | 7.42251E-02 | | |
| RESIDUALS | 6.88835E-02 | 20 | 3.44418E-03 | 21.55 | 4.35 |
| TOTAL | 1.43109E-01 | 21 | 6.81469E-03 | | |

Figure 31.

Analysis of the Relationship Between PE and PZBR

32a. Scatter Plot of 22 Standardized Values of PX vs. PZBR




| | MEAN | STD.DEV. | UNITS |
|---|---|---|---|
| PX | 0.84864 | 0.11494 | dimensionless |
| PZBR | 0.13091 | 0.07130 | dimensionless |

A: CV1
D: CV4
E: CV5
*: A,3E
#: A,E

32b. Regression Coefficients:

| VARIABLE | B(STD.V) | B | STD.ERROR(B) | T | .95 T |
|---|---|---|---|---|---|
| PZBR | -0.4739 | -7.6392E-01 | 3.1740E-01 | -2.407 | 1.725 |
| CONSTANT | 0 | 9.4864E-01 | 4.7068E-02 | 20.155 | |

32c. R-square Values:

UNADJUSTED: 0.2246 ADJUSTED: 0.1858

32d. Analysis of Variance:

| SOURCE | SS | DF | MS | F | .95 F |
|---|---|---|---|---|---|
| REGRESSION | 6.23153E-02 | 1 | 6.23153E-02 | | |
| RESIDUALS | 2.15143E-01 | 20 | 1.07572E-02 | 5.79 | 4.35 |
| TOTAL | 2.77458E-01 | 21 | 1.32123E-02 | | |

Figure 32.

Analysis of the Relationship Between PX and PZBR

agree with the expected direction of influence. When the POOL Zero Balance Rate is high, POOL Effectiveness decreases.

Figure 32 shows the regression of the POOL Depth (PX) variable on the variable PZBR. This analysis was the only one of its kind possible in this study. In this analysis, an EOM-Snapshot variable (PX) is regressed on its complementary daily average (PZBR). There does appear to be a linear relationship between these two variables, although it is not exceptionally strong. A problem here is that the two CV4 observations, which appear to be outliers, were investigated by the author and found to be valid data. These "outliers" support the statements made previously concerning the frequent random demand for Rotatable Pool items. The large fluctuation of Rotatable Pool Depth and Range, created by this frequent demand, can inflate or deflate any long-term performance measure. The POOL Depth EOM-variable is a poor measure of the monthly "strength" of the Rotatable Pool, and the author suspects that this is exactly why the PZBR data is also collected.

## H. COMMENTS

The data from five different performance variables of this study did not indicate associations with Mission Capability that agreed with the intuitive, or expected associations. These variables are the Repair Rate (MR), the AWM Rate (MM), the AWP Rate (MP), and CLAMP Range and Depth (CR and CX, respectively). CLAMP Range and Depth data both indicate a negative association with Mission Capability. This is based on their respective -0.47 and -0.35 correlations with the variable MC (from Table 11). These correlations suggest that higher values of CLAMP Range and Depth are associated with simultaneous decreases in Mission Capability.

No apparent reason for this discrepancy could be found by the author, and no attempt at explaining the phenomenon will be made.

The correlation coefficients from Table 11 which describe the association of MC with the variables MR, MM, and MP are -0.78, 0.35, and 0.06, respectively. It should be noted that the respective correlation coefficients of the individual ships are quite different from these values. For example, the MC-MR correlations from ships CV1, CV4, and CV5 are -0.26, 0.10, and -0.07, respectively. When the data are pooled, however, the -0.78 value is obtained. This suggests that the data for the MR variable were not similar enough to warrant pooling. This situation was seen earlier when the P/NMCS variable was regressed on the variable AWMC in Figure 26, and it is possible that the data from many of the other variables are similarly nonhomogeneous. This characterizes one of the major shortcomings of the data that were examined in this study. The fact that there are so few observations for each ship requires that the data be pooled, but the limited number of observations also precludes any test for the homogeneity of the pooled data.

The MM and MP variables were not examined in detail, however, it is interesting to note that these variables, along with the variable MR, are data that is not collected by the ship's Supply personnel. These data are collected by Maintenance personnel and submitted to Supply at the end of the reporting periods. It is possible that these data are being measured incorrectly or that the current definitions of the variables are inappropriate. It was not clear to the author, nor to the Code 40 Staff, whether or not components entering AWP or AWM status were being counted more than once. For example, a component could be inducted for repair

during the first week of a month and immediately go into AWM status. Thus, an AWM "event" is recorded. Then, the component could go back into repair and subsequently go into AWM status a second time in the same month. It is possible that this could happen several times in a month for a single component. If the AWM "event" is recorded each time the component goes into AWM status, the variable will not reflect the true performance. The Code 40 Staff claim that this "double-counting" does not occur, but they could not prove this to the author.

# V. CONCLUSIONS AND RECOMMENDATIONS

## A. CONCLUSIONS

In the Introduction of this report, it was observed that the concept of Supply Support Effectiveness could be collectively described by the set of data-base variables currently used to measure different categories of Supply performance. One objective of this study has been the attempt to find a proper subset of these performance variables which form a meaningful indicator of Supply Support Effectiveness. Based on the mixed results of this study, it has not been possible to combine the performance variables into a single statistic that is related to aircraft readiness.

This can be attributed partly to the fact that high multicolinearity exists in the data base, but the true reason for the weak explanatory powers of the Supply performance variables can be simply explained. These variables are defined and collected for the primary purpose of measuring <u>inventory</u> "readiness," <u>not</u> aircraft readiness. Although many associations between the performance variables and the MC and FMC Rates have been observed, the performance data, in general, are not <u>structured</u> in a manner that can be <u>directly</u> related to aircraft. For example, many of the components that are in AWP or AWM status are items that will be returned to stock when they are finally repaired. Other components, however, represent current aircraft discrepancies, and when these items are finally repaired, they will be installed in aircraft. Thus, <u>some</u> of the AWP and AWM components are directly related to PMC or NMC aircraft, but others are <u>not</u>. It is often the case that the aircraft discrepancy

can be immediately corrected from RFI stock and the non-RFI component is routinely inducted for repair as a return-to-stock item. Therefore, any true relationship which may exist between aircraft readiness and the AWP or AWM variables is concealed by the stock-replenishment components. A similar argument may be applied to the Maintenance-type variables.

The P/NMCS variable, which is the only variable of the study that is directly related to Mission Capability, was found to be the most statistically significant performance variable related to the MC Rate. It is interesting to note here that the majority of the performance variables are indicators of performance, or potential-for-performance, for the three inventory groups. P/NMCS is not characteristic of any single inventory group. It is a collective representation of the material requirements that could not be satisfied locally. Thus, it is concluded that P/NMCS is the only direct link between Supply and aircraft readiness and, consequently, this variable is the best indicator of Supply Support Effectiveness that can be determined from the performance variables currently collected.

In view of the preceding comments and conclusions, it is hardly surprising that no relationships were discovered between the Support Factors and the readiness variables. The significant relationship between the Material Support Factor-Aviation (MSFA) and P/NMCS suggests that the MSFA variable may be a useful link between P/NMCS and the inventory group variables. However, several of the variables in the MSFA equation are highly correlated, and this suggests that an equation that uses fewer variables would be equally descriptive.

Although the study was precluded from developing any significant regression models that directly relate the performance variables to the MC and FMC Rates, several additional conclusions could be drawn from the analyses results. One conclusion is the fact that a direct relationship between aircraft readiness and the collective set of Supply performance variables could not be quantifiably established; however, the general trends exhibited by the individual ship correlation matrices indicate that there is a definite positive association between Supply performance and aircraft readiness.

The results of the analyses between the P/NMCS variable and the other performance variables from the POOL and AVCAL inventory groups are significantly related to P/NMCS. Additionally, the high correlations between the POOL variables and the AWP variables suggest that the majority of the items in AWP status are components from the Rotatable Pool. This forms the basis for one of the recommendations in the next subsection.

It should be noted here that although many statisically significant relationships were discovered between several of the variables, none of these models have been utilized to make any definitive statements concerning these linear relationships. This is because of the high multicolinearity observed in the data and also because of questions raised in the previous section concerning the appropriateness and effectiveness of pooling the data. The data do not appear to be "rich" enough in terms of independent variation to allow an in-depth study of the relationships. Additionally, the monthly data are too "coarse" in terms of cause-and-effect relationships to warrant an attempt at building a model to describe Mission Capable or Full Mission Capable Rates.

The problem of multicolinearity can be attributed largely to the limited number of observations available to the study. One solution to this problem would naturally be to obtain more data samples. This option was not possible within the time limits of this study, and the only recourse was to pool the data. Unfortunately, pooling did not eliminate all of the problems; in fact, it actually created new ones for several analyses. Several cases were observed where the pooled data either concealed the true relationships between the variables, or the data clustered in groups which made analyses impractical, if not infeasible.

When the subject of intangible factors was discussed in the Introduction, it was suggested that the actual size or tonnage of a ship might be related to various performance indicators or to the readiness values. This area has not been analyzed in this report; however, it does appear that a size-related factor has an influence on several of the performance variables. It has not been determined whether or not this factor has an effect on the results of any particular analysis of variables; however, several cases were observed in which the size factor had an effect on the analysis technique employed, namely, the pooling process. In the analysis of the variables P/NMCS and AVLI, it was observed that the sizes of each ship's AVCAL inventory could be easily distinguished from each other. The size of each ship's AVCAL inventory also happens to correspond to the size of the applicable ship. Although not presented in this report, this type of situation was observed for the other inventory groups when the data was pooled. This suggests that analyses which involve these types of variables should be performed for individual ships, rather than using a pooled set of data. It should be noted that the influence

of ship size was most frequently observed in variables that reported end-of-the-month-type observations. Variables that reported rate-type data did not appear to be influenced by this factor. This supports a final conclusion concerning the use of end-of-the-month data.

The EOM-Snapshot variables are poor measures of performance or potential-for-performance when compared to the monthly-type data. As discussed in the previous section, EOM-Snapshot variables may artificially inflate or deflate the true measure of performance, and there is little question as to why they fail to show strong associations with aircraft readiness. Although the information reported by an EOM-Snapshot variable is "current" at the end of a month, it is "after-the-fact" with respect to the monthly-type data. The only exception to this conclusion was observed with the AVCAL Range variable, which was seen to be a significant variable in the regression model which used the MC Rate as the dependent variable and also in the regression model which used P/NMCS as the dependent variable.

## B. RECOMMENDATIONS

Because the P/NMCS variable has been observed to be the best indicator of Supply Support effectiveness, it is recommended that the PMCS and NMCS requisition totals be maintained separately in future records. Since PMC discrepancies are the only differences between Full Mission Capable aircraft and Mission Capable aircraft, the additional collection of PMCS data could provide the basis for a future analysis of the difference between the FMC Rate and the MC Rate.

It is recommended that the twice-monthly AMR report be revised so that each report reflects only the data that is applicable to the 15 day

period covered. This would effectively double the number of available observations and simultaneously reduce some of the "coarseness" of the data. Moreover, the concept of data collection at specified intervals of the calendar month should be reviewed. Aircraft carrier deployments do not always begin or end of the first day of a month. Because of this, the first and last month's data from a ship's deployment may not be suitable for analysis with data collected in other months. It should be noted here that COMNAVAIRPAC has developed a new Weekly Management Information Report that is much more comprehensive than the AMR Report. This new report is submitted by deployed ships at the end of each week; however, the end of the "week" is based on the actual start of the deployment and not by the calendar week. It is suspected that this report will eventually replace the AMR Report. If this occurs, a larger data base can be developed which can be analyzed in greater detail.

It has been concluded that the EOM-Snapshot variables are poor performance statistics, and it is suggested that the data collection methodologies be unified so that the data from each variable are equally representative over the time period covered by each report.

The Gross and Net Effectiveness variables for the AVCAL inventory group are highly correlated. This creates a redundancy in the MSFA Support Factor equation which may artificially inflate the proper value. It is suggested that the AVCAL Net Effectiveness variable be removed from the equation and the denominator value adjusted accordingly. This situation may also apply to the Range and Depth variables in the equation; however, the correlations between Range and Depth, though large, are not as high as the correlation of AVCAL Gross and Net Effectiveness.

It has been concluded that P/NMCS is the best indicator of Supply Support Effectiveness. It has also been observed that P/NMCS is strongly related to POOL Effectiveness, POOL Range, and AVCAL Range. Furthermore, there exist large correlations between the POOL variables and the AWP variables, which suggest that the majority of components awaiting parts are items from the Rotatable Pool. In view of these relationships and associations, it is recommended that the AVCAL Range and Depth of bit-and-piece repair parts for the repairable components in the Rotatable Pool be increased on all ships.

## C. AREAS OF FURTHER STUDY

The field of study examined in this report is relatively new. The results, conclusions, and recommendations presented here have only begun to address the problem of identifying the significant relationships in the data base. Although limited in scope by the available data, this study may help guide the way to more expanded analyses of the relationships between aircraft readiness and Supply Support Effectiveness.

A model which can be used to forecast aircraft readiness remains to be developed. In order to build such a model, it will be necessary to incorporate the data from many areas that are not directly associated with, or influenced by, the activities of Supply. As stated earlier, additional maintenance data, aircraft data, cannibalization data, and intangible-related data must be utilized. Prior to developing a large-scale model such as this, it will also be necessary to determine which data are important to the model and which are not.

In Section III, two analytical techniques not employed in this study were briefly discussed. These methods are time-series analysis

and principal component analysis. The monthly data of the present study did not lend themselves to analyses by time-series methods. Many of the regression analyses performed in this study hinted at signs of autocorrelation in the data. The new weekly report that was mentioned earlier will open the door to a great number of possible analyses. When a sufficient number of these data are collected, both time-series analysis and principal component analysis should be attempted on them.

What is really needed is an in-depth and detailed study of the day-to-day records and transactions over the entire deployment of a ship. It was seen earlier that a number of problems in the present study developed when the data from different ships were pooled. It is likely that no two ships are similar enough to enable a complete analysis of all variables using a pooled data set. The requirement of submitting daily reports would be prohibitive to efficient afloat operations; however, the ship's records could be analyzed upon completion of the deployment.

It would also be interesting to do an analysis based on individual aircraft types. The MC and FMC data do not distinguish between aircraft, nor do the Supply data indicate the end-users of material. Different aircraft experience different problems, and it is frequently observed that one aircraft type invariably enjoys higher aggregate levels of readiness than another. It is quite possible that different areas of Supply performance have different influences on the readiness of the various aircraft types. This could be investigated by retrieving data from SUADPS records, since demands for material and Supply requisitions are also coded by aircraft type.

A final area of study suggested here is the modeling of the inventory groups or the repair activity using queueing theory and Monte Carlo simulation. If the random demand for material in the inventory groups could be determined or estimated, this could be useful in the forecasting model.

## APPENDIX A. MEAN VALUES OF VARIABLES

Tables 3 through 8 list the mean values and standard deviations of the aircraft carrier performance variables. These values are based on the raw data listed in Appendix C. For security reasons, the mean values and standard deviations of the variables, MC and FMC, have been omitted.

Table 3 lists the values obtained by pooling all 32 observations. Tables 4 through 8 list the mean values and standard deviations based on the individual observations from ships CV1 through CV5, respectively.

TABLE 3

MEAN VALUES OF PERFORMANCE VARIABLES BASED ON POOLED DATA FROM SHIPS CV1, CV2, CV3, CV4, CV5

| Variable | Mean | Standard Deviation |
|---|---|---|
| MSPA | .805482 | 5.25689E-02 |
| CRF | .731796 | 7.57121E-02 |
| P/NMCS | 145.250 | 83.6930 |
| AD | 4749.31 | 2378.50 |
| AG | .633750 | .102980 |
| AN | .774375 | 8.11583E-02 |
| AR | .875937 | 7.29497E-02 |
| AVLI | 41013.7 | 8589.64 |
| AX | .816250 | 4.77054E-02 |
| AWMC | 196.500 | 151.643 |
| AWPC | 345.406 | 169.392 |
| AWPR | 464.094 | 218.391 |
| AWP30 | 80.6250 | 68.0567 |
| AWP60 | 43.5625 | 42.1915 |
| CD | 693.219 | 526.585 |
| CG | .787187 | 8.35206E-02 |
| CLLI | 2119.50 | 1102.37 |
| CN | .806875 | 8.79309E-02 |
| COM | 2786.91 | 1837.17 |
| CR | .930000 | 4.57200E-02 |
| CX | .882500 | 5.81432E-02 |
| MM | .129375 | 8.13568E-02 |
| MP | .140312 | 7.78950E-02 |
| MR | .698437 | 6.97510E-02 |
| PD | 721.281 | 295.408 |
| PE | .898438 | 7.74641E-02 |
| POLI | 217.750 | 49.4551 |
| PR | .936250 | 5.98249E-02 |
| PX | .825937 | .117689 |
| PZBR | .124063 | 6.54935E-02 |

TABLE 4

MEAN VALUES OF PERFORMANCE VARIABLES BASED ON

DATA FROM SHIP CV1

| Variable | Mean | Standard Deviation |
|---|---|---|
| MSFA | .771590 | 4.04661E-02 |
| CRF | .698125 | 9.06085E-02 |
| P/MMCS | 160.500 | 41.2027 |
| AD | 5386.75 | 2752.87 |
| AG | .540000 | .106771 |
| AM | .722500 | 8.65544E-02 |
| AR | .812500 | 1.89297E-02 |
| AVLI | 44722.2 | 516.861 |
| AX | .780000 | 2.44949E-02 |
| AWMC | 367.250 | 81.2091 |
| AWPC | 401.250 | 197.265 |
| AWPR | 397.750 | 172.653 |
| AWP30 | 49.5000 | 37.6785 |
| AWP60 | 12.0000 | 22.6863 |
| CD | 1196.25 | 493.256 |
| CG | .730000 | 4.08248E-02 |
| CLLI | 3188.00 | .0 |
| CM | .740000 | 3.65148E-02 |
| COM | 2785.00 | 1095.88 |
| CR | .952500 | 9.57426E-03 |
| CX | .930000 | 1.15470E-02 |
| MM | .192500 | 7.32006E-02 |
| MP | .152500 | 5.31507E-02 |
| MR | .667500 | 4.64579E-02 |
| PD | 732.250 | 247.575 |
| PE | .902500 | 1.70783E-02 |
| POLI | 278.250 | 1.50000 |
| PR | .980000 | 2.70801E-02 |
| PX | .900000 | 6.00000E-02 |
| PZBR | .112500 | 7.13559E-02 |

TABLE 5

MEAN VALUES OF PERFORMANCE VARIABLES BASED ON

DATA FROM SHIP CV2

| Variable | Mean | Standard Deviation |
|---|---|---|
| MSPA | .850226 | 4.45938E-02 |
| CRP | .694375 | 2.79415E-02 |
| P/MMCS | 149.250 | 42.1298 |
| AD | 4784.75 | 3458.26 |
| AG | .715000 | 5.77353E-03 |
| AN | .840000 | 8.16498E-03 |
| AR | .882500 | 2.21736E-02 |
| AVLI | 52357.2 | 3284.69 |
| AX | .847500 | 3.20156E-02 |
| AWMC | 124.500 | 61.7549 |
| AWPC | 243.500 | 101.668 |
| AWPR | 450.000 | 240.351 |
| AWP30 | 71.7500 | 45.3312 |
| AWP60 | 34.5000 | 23.8118 |
| CD | 906.000 | 639.616 |
| CG | .780000 | .154488 |
| CLLI | 3251.50 | 214.385 |
| CN | .822500 | .136717 |
| COM | 2070.50 | 1547.18 |
| CR | .952500 | 7.50000E-02 |
| CX | .952500 | 7.50000E-02 |
| MN | .167500 | 6.07591E-02 |
| MP | .152500 | 3.40343E-02 |
| MR | .752500 | 3.59398E-02 |
| PD | 703.750 | 380.735 |
| PE | .922500 | 3.59398E-02 |
| POLI | 232.250 | 10.1776 |
| PR | .982500 | 1.50000E-02 |
| PX | .887500 | 6.07591E-02 |
| PZBR | .162500 | 1.50000E-02 |

## TABLE 6

## MEAN VALUES OF PERFORMANCE VARIABLES BASED ON DATA FROM SHIP CV3

| Variable | Mean | Standard Deviation |
|---|---|---|
| MSPA | .845983 | 4.95966E-02 |
| CRF | .805416 | 5.52137E-02 |
| P/MHCS | 78.8333 | 10.0681 |
| AD | 3863.17 | 2101.36 |
| AG | .685000 | .156173 |
| AM | .821667 | .104578 |
| AR | .868333 | 5.84522E-02 |
| AVLI | 27851.3 | 391.803 |
| AX | .828333 | 5.15429E-02 |
| AWMC | 138.333 | 32.5556 |
| AWPC | 214.167 | 64.9412 |
| AWPR | 361.000 | 114.546 |
| AWP30 | 27.0000 | 24.6982 |
| AWP60 | 8.16667 | 4.70815 |
| CD | 173.833 | 87.6297 |
| CG | .885000 | 6.18870E-02 |
| CLLI | 563.000 | 12.0000 |
| CM | .885000 | 6.18870E-02 |
| COH | 1634.17 | 676.315 |
| CR | .961667 | 2.78687E-02 |
| CX | .880000 | 5.32916E-02 |
| MM | .700000 | 7.15541E-02 |
| MP | .105000 | 5.46809E-02 |
| MR | .686667 | 8.91441E-02 |
| PD | 572.667 | 277.550 |
| PE | .963333 | 1.21106E-02 |
| POLI | 135.000 | 2.00000 |
| PR | .951667 | 2.04124E-02 |
| PX | .701667 | 6.58534E-02 |
| PZBR | .073333 | 2.50333E-02 |

TABLE 7

MEAN VALUES OF PERFORMANCE VARIABLES BASED ON

DATA FROM SHIP CV4

| Variable | Mean | Standard Deviation |
|---|---|---|
| MSFA | .755584 | 4.31950E-02 |
| CRF | .726071 | 7.58130E-02 |
| P/WMCS | 271.143 | 73.1538 |
| AD | 4314.00 | 2545.56 |
| AG | .581429 | 7.42582E-02 |
| AN | .747143 | 8.34095E-02 |
| AR | .804286 | 3.40867E-02 |
| AVLI | 49173.1 | 1433.91 |
| AX | .782857 | 2.36039E-02 |
| AWMC | 356.714 | 168.176 |
| AWPC | 561.571 | 169.115 |
| AWPR | 602.286 | 334.194 |
| AWP30 | 158.286 | 97.4794 |
| AWP60 | 78.4286 | 64.4951 |
| CD | 980.143 | 632.309 |
| CG | .740000 | 5.68624E-02 |
| CLLI | 3211.14 | 238.391 |
| CN | .760000 | .106927 |
| COM | 5017.86 | 2148.59 |
| CR | .934286 | 1.81265E-02 |
| CX | .888571 | 2.85357E-02 |
| MM | .084286 | 4.15761E-02 |
| MP | .127143 | 4.02965E-02 |
| MR | .774286 | 4.57737E-02 |
| PD | 909.000 | 405.765 |
| PE | .807143 | .115717 |
| POLI | 254.857 | 23.3054 |
| PR | .890000 | 9.83192E-02 |
| PX | .740000 | .151437 |
| PZBR | .191429 | 8.83984E-02 |

TABLE 8

MEAN VALUES OF PERFORMANCE VARIABLES BASED ON

DATA FROM SHIP CV5

| Variable | Mean | Standard Deviation |
|---|---|---|
| MSPA | .811197 | 3.32619E-02 |
| CRF | .721136 | 7.54101E-02 |
| P/MMCS | 94.3636 | 26.8673 |
| AD | 5265.00 | 2126.26 |
| AG | .643636 | 6.46951E-02 |
| AN | .760909 | 6.04077E-02 |
| AR | .946364 | 5.59058E-02 |
| AVLI | 37527.4 | 1789.63 |
| AX | .832727 | 5.31208E-02 |
| AWMC | 90.3636 | 67.3665 |
| AWPC | 296.182 | 61.6162 |
| AWPR | 461.636 | 162.534 |
| AWP30 | 75.0000 | 30.1430 |
| AWP60 | 55.4546 | 22.3041 |
| CD | 533.636 | 230.932 |
| CG | .787273 | 3.84944E-02 |
| CLLI | 1473.64 | 57.7031 |
| CN | .812727 | 4.54072E-02 |
| COM | 2257.18 | 1261.28 |
| CR | .893636 | 4.12971E-02 |
| CX | .837273 | 4.12531E-02 |
| MM | .153636 | 8.85745E-02 |
| MP | .159091 | .117342 |
| MR | .648182 | 1.94001E-02 |
| PD | 685.273 | 178.407 |
| PE | .910909 | 3.53425E-02 |
| POLI | 212.000 | 23.7781 |
| PR | .924545 | 3.72461E-02 |
| PX | .899091 | 2.80907E-02 |
| PZBR | .099091 | 2.54772E-02 |

# APPENDIX B. CORRELATION MATRICES

Tables 9 through 16 list the correlation matrices of the aircraft carrier performance variables. These matrices are based on the raw data listed in Appendix C. The coefficients of correlation between any two variables may be found by entering the applicable column for one variable and finding the row entry corresponding to the other variable.

Table 9 represents the correlation values based on all 32 observations. Table 10 is the correlation matrix of the revised subset of 28 observations with ship CV2 data omitted. Table 11 is based on the 22 pooled observations from ships CV1, CV4, and CV5. Tables 12-16 are the correlation matrices based on the individual observations from ships CV1 through CV5, respectively.

## TABLE 9

## CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON POOLED DATA FROM SHIPS CV1, CV2, CV3, CV4, CV5

| | MC | FMC | MSFA | CRF | P/NMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.71 | 1.00 | | | | | | | |
| MSFA | 0.33 | 0.27 | 1.00 | | | | | | |
| CRF | -0.09 | 0.04 | 0.15 | 1.00 | | | | | |
| P/NMCS | -0.57 | -0.50 | -0.67 | -0.26 | 1.00 | | | | |
| AD | 0.11 | 0.10 | 0.05 | -0.07 | -0.06 | 1.00 | | | |
| AG | 0.26 | 0.14 | 0.77 | 0.05 | -0.32 | 0.14 | 1.00 | | |
| AN | 0.13 | 0.13 | 0.77 | -0.01 | -0.25 | 0.11 | 0.94 | 1.00 | |
| AR | 0.49 | 0.24 | 0.60 | -0.05 | -0.59 | 0.05 | 0.47 | 0.37 | 1.00 |
| AVLI | -0.21 | -0.43 | -0.32 | -0.35 | 0.64 | 0.09 | -0.21 | -0.13 | -0.35 |
| AX | 0.28 | 0.10 | 0.76 | -0.01 | -0.44 | -0.02 | 0.63 | 0.58 | 0.76 |
| AWMC | -0.50 | -0.27 | -0.55 | -0.25 | 0.69 | 0.07 | -0.33 | -0.27 | -0.65 |
| AWPC | -0.54 | -0.42 | -0.46 | 0.01 | 0.60 | 0.38 | -0.20 | -0.15 | -0.44 |
| AWPR | -0.29 | -0.29 | -0.20 | 0.02 | 0.32 | 0.51 | 0.15 | 0.07 | -0.21 |
| AWP30 | -0.43 | -0.50 | -0.43 | -0.08 | 0.61 | 0.24 | -0.09 | -0.15 | -0.30 |
| AWP60 | -0.28 | -0.43 | -0.22 | -0.33 | 0.31 | 0.10 | 0.11 | 0.07 | -0.01 |
| CD | -0.18 | -0.13 | -0.21 | -0.24 | 0.30 | 0.54 | -0.11 | -0.04 | -0.36 |
| CG | 0.00 | 0.07 | 0.60 | 0.33 | -0.54 | -0.13 | 0.18 | 0.20 | 0.32 |
| CLLI | -0.26 | -0.35 | -0.37 | -0.36 | 0.69 | 0.04 | -0.28 | -0.16 | -0.46 |
| CN | 0.10 | 0.10 | 0.65 | 0.20 | -0.53 | -0.09 | 0.16 | 0.19 | 0.38 |
| COM | -0.57 | -0.40 | -0.43 | 0.01 | 0.55 | 0.26 | -0.12 | -0.08 | -0.43 |
| CR | -0.45 | -0.22 | 0.15 | 0.28 | 0.04 | -0.12 | -0.02 | 0.06 | -0.37 |
| CX | -0.25 | -0.15 | 0.12 | -0.04 | 0.16 | -0.11 | -0.12 | -0.02 | -0.33 |
| MM | 0.27 | 0.14 | 0.05 | -0.78 | -0.08 | 0.08 | -0.13 | -0.11 | 0.25 |
| MP | 0.11 | -0.03 | -0.16 | -0.70 | 0.10 | 0.06 | -0.19 | -0.17 | 0.11 |
| MR | -0.59 | -0.65 | -0.18 | 0.27 | 0.54 | 0.09 | -0.00 | 0.02 | -0.42 |
| PD | -0.28 | -0.21 | -0.09 | 0.08 | 0.20 | 0.57 | 0.10 | 0.11 | -0.20 |
| PE | 0.38 | 0.39 | 0.65 | 0.36 | -0.82 | -0.05 | 0.14 | 0.14 | 0.36 |
| POLI | -0.12 | -0.17 | -0.37 | -0.39 | 0.52 | 0.06 | -0.38 | -0.31 | -0.24 |
| PR | 0.21 | 0.28 | 0.40 | 0.03 | -0.40 | -0.23 | -0.07 | 0.00 | 0.10 |
| PX | 0.47 | 0.28 | 0.35 | -0.24 | -0.39 | 0.31 | 0.13 | 0.13 | 0.48 |
| PZBR | -0.34 | -0.39 | -0.28 | -0.52 | 0.61 | 0.06 | 0.10 | 0.18 | -0.32 |

| | AVLI | AX | AWHC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | -0.22 | 1.00 | | | | | | | |
| AWHC | 0.39 | -0.49 | 1.00 | | | | | | |
| AWPC | 0.47 | -0.32 | 0.66 | 1.00 | | | | | |
| AWPR | 0.27 | -0.12 | 0.41 | 0.75 | 1.00 | | | | |
| AWP30 | 0.44 | -0.19 | 0.53 | 0.81 | 0.82 | 1.00 | | | |
| AWP60 | 0.29 | 0.00 | 0.20 | 0.54 | 0.61 | 0.71 | 1.00 | | |
| CD | 0.59 | -0.25 | 0.54 | 0.70 | 0.60 | 0.49 | 0.37 | 1.00 | |
| CG | -0.47 | 0.40 | -0.35 | -0.39 | -0.17 | -0.25 | -0.22 | -0.34 | 1.00 |
| CLLI | 0.96 | -0.27 | 0.53 | 0.51 | 0.19 | 0.38 | 0.21 | 0.62 | -0.50 |
| CN | -0.35 | 0.45 | -0.42 | -0.48 | -0.31 | -0.39 | -0.32 | -0.32 | 0.90 |
| COH | 0.44 | -0.39 | 0.59 | 0.85 | 0.75 | 0.71 | 0.54 | 0.72 | -0.36 |
| CR | 0.13 | -0.03 | 0.24 | 0.06 | 0.05 | -0.03 | -0.26 | 0.14 | 0.34 |
| CX | 0.44 | 0.14 | 0.18 | 0.03 | -0.09 | -0.00 | -0.14 | 0.26 | 0.14 |
| SH | 0.15 | 0.25 | 0.09 | -0.19 | -0.17 | -0.09 | -0.03 | 0.12 | -0.02 |
| SP | 0.05 | 0.02 | 0.11 | -0.05 | -0.17 | 0.02 | 0.08 | -0.00 | -0.23 |
| SR | 0.52 | -0.17 | 0.37 | 0.50 | 0.42 | 0.46 | 0.16 | 0.39 | -0.17 |
| PD | 0.31 | -0.16 | 0.38 | 0.72 | 0.73 | 0.61 | 0.47 | 0.78 | -0.16 |
| PE | -0.45 | 0.38 | -0.53 | -0.51 | -0.43 | -0.59 | -0.54 | -0.24 | 0.55 |
| POLI | 0.78 | -0.19 | 0.50 | 0.51 | 0.18 | 0.35 | 0.24 | 0.58 | -0.48 |
| PR | -0.03 | 0.22 | -0.16 | -0.40 | -0.50 | -0.50 | -0.39 | -0.12 | 0.33 |
| PX | 0.22 | 0.31 | -0.33 | -0.07 | -0.15 | -0.26 | 0.01 | 0.24 | -0.14 |
| PZBR | 0.59 | -0.26 | 0.40 | 0.34 | 0.33 | 0.36 | 0.56 | 0.42 | -0.46 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | -0.41 | 1.00 | | | | | | | |
| COM | 0.44 | -0.45 | 1.00 | | | | | | |
| CR | 0.17 | 0.20 | 0.13 | 1.00 | | | | | |
| CX | 0.50 | 0.16 | -0.02 | 0.69 | 1.00 | | | | |
| MM | 0.18 | 0.07 | -0.28 | -0.14 | 0.17 | 1.00 | | | |
| MP | 0.06 | -0.10 | -0.19 | -0.40 | -0.13 | 0.71 | 1.00 | | |
| MR | 0.49 | -0.19 | 0.59 | 0.35 | 0.35 | -0.41 | -0.32 | 1.00 | |
| PD | 0.29 | -0.26 | 0.80 | 0.07 | -0.00 | -0.18 | -0.20 | 0.50 | 1.00 |
| PE | -0.44 | 0.58 | -0.52 | 0.16 | 0.11 | 0.10 | -0.08 | -0.30 | -0.18 |
| POLI | 0.86 | -0.34 | 0.38 | -0.06 | 0.31 | 0.35 | 0.16 | 0.24 | 0.28 |
| PR | 0.04 | 0.39 | -0.44 | 0.26 | 0.40 | 0.28 | 0.08 | -0.21 | -0.31 |
| PX | 0.19 | 0.02 | -0.19 | -0.24 | 0.04 | 0.37 | 0.18 | -0.29 | 0.05 |
| PZBR | 0.55 | -0.39 | 0.49 | -0.03 | 0.10 | -0.06 | -0.02 | 0.40 | 0.29 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | -0.29 | 1.00 | | | |
| PR | 0.60 | 0.10 | 1.00 | | |
| PX | 0.37 | 0.40 | 0.46 | 1.00 | |
| PZBR | -0.70 | 0.33 | -0.38 | -0.11 | 1.00 |

TABLE 10

CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON

POOLED DATA FROM SHIPS CV1, CV3, CV4, CV5

| | MC | FMC | MSFA | CRF | P/NMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.79 | 1.00 | | | | | | | |
| MSFA | 0.38 | 0.47 | 1.00 | | | | | | |
| CRF | -0.04 | 0.04 | 0.24 | 1.00 | | | | | |
| P/NMCS | -0.67 | -0.61 | -0.71 | -0.26 | 1.00 | | | | |
| AD | 0.18 | 0.16 | -0.02 | -0.04 | -0.03 | 1.00 | | | |
| AG | 0.21 | 0.21 | 0.77 | 0.12 | -0.35 | 0.15 | 1.00 | | |
| AN | 0.07 | 0.20 | 0.77 | 0.05 | -0.27 | 0.12 | 0.93 | 1.00 | |
| AR | 0.55 | 0.31 | 0.63 | -0.05 | -0.58 | 0.03 | 0.49 | 0.37 | 1.00 |
| AVLI | -0.37 | -0.43 | -0.67 | -0.31 | 0.77 | 0.08 | -0.44 | -0.36 | -0.44 |
| AX | 0.31 | 0.23 | 0.73 | 0.04 | -0.44 | -0.09 | 0.61 | 0.56 | 0.78 |
| AWMC | -0.51 | -0.36 | -0.55 | -0.28 | 0.72 | 0.03 | -0.30 | -0.24 | -0.66 |
| AWPC | -0.50 | -0.47 | -0.50 | -0.04 | 0.67 | 0.37 | -0.15 | -0.09 | -0.47 |
| AWPR | -0.23 | -0.30 | -0.32 | 0.02 | 0.39 | 0.48 | 0.17 | 0.07 | -0.25 |
| AWP30 | -0.40 | -0.54 | -0.52 | -0.09 | 0.66 | 0.19 | -0.08 | -0.15 | -0.33 |
| AWP60 | -0.23 | -0.43 | -0.26 | -0.37 | 0.34 | 0.08 | 0.14 | 0.10 | -0.02 |
| CD | -0.18 | -0.13 | -0.40 | -0.23 | 0.37 | 0.51 | -0.18 | -0.11 | -0.42 |
| CG | 0.22 | 0.30 | 0.62 | 0.39 | -0.55 | -0.36 | 0.24 | 0.26 | 0.33 |
| CLLI | -0.40 | -0.34 | -0.62 | -0.32 | 0.76 | 0.03 | -0.46 | -0.33 | -0.53 |
| CN | 0.26 | 0.31 | 0.64 | 0.23 | -0.52 | -0.25 | 0.17 | 0.19 | 0.38 |
| COM | -0.56 | -0.51 | -0.48 | -0.01 | 0.61 | 0.26 | -0.08 | -0.05 | -0.46 |
| CR | -0.46 | -0.09 | -0.06 | 0.38 | 0.14 | -0.35 | -0.11 | -0.02 | -0.51 |
| CX | -0.34 | 0.02 | -0.19 | 0.05 | 0.27 | -0.32 | -0.36 | -0.23 | -0.48 |
| MM | 0.29 | 0.19 | -0.06 | -0.78 | -0.06 | -0.02 | -0.20 | -0.19 | 0.25 |
| MP | 0.07 | -0.04 | -0.17 | -0.71 | 0.08 | 0.10 | -0.22 | -0.20 | 0.12 |
| MR | -0.70 | -0.68 | -0.37 | 0.35 | 0.60 | 0.06 | -0.11 | -0.09 | -0.48 |
| PD | -0.26 | -0.26 | -0.18 | 0.11 | 0.27 | 0.51 | 0.12 | 0.13 | -0.24 |
| PE | 0.43 | 0.51 | 0.65 | 0.39 | -0.82 | -0.09 | 0.11 | 0.10 | 0.35 |
| POLI | -0.15 | -0.16 | -0.47 | -0.38 | 0.54 | 0.05 | -0.44 | -0.37 | -0.25 |
| PR | 0.18 | 0.40 | 0.32 | 0.09 | -0.42 | -0.30 | -0.18 | -0.10 | 0.09 |
| PX | 0.50 | 0.41 | 0.29 | -0.21 | -0.40 | 0.30 | 0.07 | 0.07 | 0.48 |
| PZBR | -0.45 | -0.44 | -0.38 | -0.50 | 0.63 | 0.06 | 0.03 | 0.12 | -0.34 |

| | AVLI | AX | AWHC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | -0.47 | 1.00 | | | | | | | |
| AWHC | 0.58 | -0.48 | 1.00 | | | | | | |
| AWPC | 0.70 | -0.33 | 0.66 | 1.00 | | | | | |
| AWPR | 0.31 | -0.20 | 0.43 | 0.76 | 1.00 | | | | |
| AWP30 | 0.53 | -0.23 | 0.54 | 0.82 | 0.81 | 1.00 | | | |
| AWP60 | 0.38 | -0.01 | 0.20 | 0.52 | 0.60 | 0.71 | 1.00 | | |
| CD | 0.61 | -0.39 | 0.61 | 0.77 | 0.57 | 0.47 | 0.38 | 1.00 | |
| CG | -0.75 | 0.37 | -0.44 | -0.63 | -0.46 | -0.45 | -0.40 | -0.67 | 1.00 |
| CLLI | 0.96 | -0.44 | 0.67 | 0.68 | 0.21 | 0.44 | 0.26 | 0.64 | -0.70 |
| CN | -0.60 | 0.40 | -0.47 | -0.65 | -0.56 | -0.56 | -0.46 | -0.59 | 0.87 |
| COM | 0.61 | -0.43 | 0.60 | 0.86 | 0.75 | 0.71 | 0.54 | 0.75 | -0.59 |
| CR | -0.04 | -0.23 | 0.33 | 0.01 | -0.14 | -0.15 | -0.41 | -0.05 | 0.08 |
| CX | 0.23 | -0.08 | 0.34 | 0.08 | -0.27 | -0.08 | -0.22 | 0.10 | -0.11 |
| MM | 0.05 | 0.19 | 0.11 | -0.20 | -0.26 | -0.14 | -0.04 | 0.01 | -0.13 |
| MP | 0.04 | 0.03 | 0.13 | -0.02 | -0.13 | 0.05 | 0.11 | 0.04 | -0.19 |
| MR | 0.43 | -0.31 | 0.47 | 0.61 | 0.43 | 0.49 | 0.17 | 0.35 | -0.33 |
| PD | 0.37 | -0.24 | 0.39 | 0.75 | 0.70 | 0.59 | 0.48 | 0.77 | -0.41 |
| PE | -0.63 | 0.35 | -0.52 | -0.54 | -0.51 | -0.63 | -0.57 | -0.33 | 0.59 |
| POLI | 0.85 | -0.24 | 0.54 | 0.56 | 0.17 | 0.36 | 0.24 | 0.60 | -0.63 |
| PN | -0.23 | 0.14 | -0.11 | -0.38 | -0.58 | -0.54 | -0.41 | -0.21 | 0.38 |
| PX | 0.13 | 0.26 | -0.31 | -0.05 | -0.18 | -0.28 | 0.01 | 0.22 | -0.23 |
| PZBR | 0.58 | -0.33 | 0.46 | 0.43 | 0.38 | 0.40 | 0.62 | 0.44 | -0.53 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | -0.58 | 1.00 | | | | | | | |
| COM | 0.56 | -0.63 | 1.00 | | | | | | |
| CR | 0.09 | -0.08 | 0.09 | 1.00 | | | | | |
| CX | 0.41 | -0.09 | -0.02 | 0.59 | 1.00 | | | | |
| MM | 0.12 | -0.02 | -0.32 | -0.33 | 0.03 | 1.00 | | | |
| MP | 0.05 | -0.05 | -0.15 | -0.42 | -0.13 | 0.76 | 1.00 | | |
| MR | 0.42 | -0.35 | 0.67 | 0.27 | 0.20 | -0.54 | -0.34 | 1.00 | |
| PD | 0.34 | -0.48 | 0.83 | -0.10 | -0.15 | -0.31 | -0.17 | 0.55 | 1.00 |
| PE | -0.55 | 0.59 | -0.56 | 0.08 | 0.00 | 0.06 | -0.07 | -0.39 | -0.23 |
| POLI | 0.89 | -0.44 | 0.41 | -0.13 | 0.30 | 0.33 | 0.17 | 0.21 | 0.29 |
| PR | -0.10 | 0.40 | -0.45 | 0.21 | 0.30 | 0.24 | 0.08 | -0.34 | -0.38 |
| PX | 0.11 | -0.04 | -0.17 | -0.41 | -0.12 | 0.34 | 0.18 | -0.39 | 0.03 |
| PZBR | 0.53 | -0.44 | 0.57 | -0.06 | 0.02 | -0.10 | -0.04 | 0.37 | 0.34 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | -0.32 | 1.00 | | | |
| PR | 0.60 | 0.06 | 1.00 | | |
| PX | 0.35 | 0.39 | 0.43 | 1.00 | |
| PZBR | -0.75 | 0.32 | -0.48 | -0.16 | 1.00 |

TABLE 11

CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON

POOLED DATA FROM SHIPS CV1, CV4, CV5

| | MC | FMC | MSFA | CRF | P/NMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.80 | 1.00 | | | | | | | |
| MSFA | 0.52 | 0.44 | 1.00 | | | | | | |
| CRF | 0.03 | -0.05 | -0.01 | 1.00 | | | | | |
| P/NMCS | -0.83 | -0.68 | -0.74 | -0.10 | 1.00 | | | | |
| AD | 0.19 | 0.29 | 0.00 | 0.01 | -0.15 | 1.00 | | | |
| AG | 0.28 | 0.11 | 0.67 | -0.07 | -0.37 | 0.11 | 1.00 | | |
| AN | 0.06 | 0.08 | 0.64 | -0.21 | -0.20 | 0.10 | 0.88 | 1.00 | |
| AR | 0.60 | 0.37 | 0.76 | -0.05 | -0.69 | -0.06 | 0.56 | 0.39 | 1.00 |
| AVLI | -0.78 | -0.56 | -0.62 | 0.08 | 0.81 | -0.16 | -0.46 | -0.18 | -0.82 |
| AX | 0.39 | 0.23 | 0.74 | -0.07 | -0.45 | -0.17 | 0.58 | 0.50 | 0.79 |
| ANMC | -0.60 | -0.39 | -0.61 | -0.20 | 0.70 | -0.02 | -0.38 | -0.25 | -0.73 |
| ANPC | -0.68 | -0.54 | -0.47 | 0.19 | 0.60 | 0.29 | -0.12 | 0.01 | -0.61 |
| ANPR | -0.31 | -0.33 | -0.35 | 0.14 | 0.33 | 0.42 | 0.22 | 0.11 | -0.33 |
| ANP30 | -0.56 | -0.66 | -0.53 | 0.10 | 0.60 | 0.13 | 0.00 | -0.07 | -0.42 |
| ANP60 | -0.34 | -0.48 | -0.09 | -0.23 | 0.21 | -0.02 | 0.42 | 0.36 | -0.06 |
| CD | -0.29 | -0.07 | -0.25 | -0.01 | 0.22 | 0.49 | -0.07 | 0.08 | -0.56 |
| CG | 0.41 | 0.16 | 0.66 | 0.08 | -0.47 | -0.27 | 0.31 | 0.19 | 0.65 |
| CLLI | -0.69 | -0.36 | -0.52 | -0.01 | 0.74 | -0.18 | -0.48 | -0.14 | -0.81 |
| CN | 0.36 | 0.20 | 0.68 | -0.04 | -0.42 | -0.12 | 0.19 | 0.13 | 0.56 |
| COM | -0.69 | -0.56 | -0.47 | 0.15 | 0.55 | 0.16 | -0.02 | 0.06 | -0.56 |
| CR | -0.47 | -0.18 | -0.41 | 0.22 | 0.41 | -0.25 | -0.36 | -0.24 | -0.59 |
| CX | -0.35 | 0.01 | -0.37 | -0.02 | 0.39 | -0.25 | -0.58 | -0.36 | -0.59 |
| MM | 0.35 | 0.40 | 0.23 | -0.72 | -0.24 | -0.04 | -0.08 | -0.02 | 0.28 |
| MP | 0.06 | 0.03 | -0.03 | -0.68 | -0.01 | 0.10 | -0.19 | -0.12 | 0.15 |
| MR | -0.78 | -0.75 | -0.62 | 0.36 | 0.75 | -0.11 | -0.35 | -0.27 | -0.66 |
| PD | -0.39 | -0.30 | -0.18 | 0.20 | 0.19 | 0.40 | 0.15 | 0.18 | -0.38 |
| PE | 0.55 | 0.53 | 0.62 | 0.26 | -0.78 | 0.01 | -0.05 | -0.09 | 0.43 |
| POLI | -0.43 | -0.04 | -0.17 | -0.02 | 0.41 | -0.25 | -0.46 | -0.18 | -0.53 |
| PR | 0.21 | 0.40 | 0.35 | -0.01 | -0.38 | -0.25 | -0.27 | -0.17 | 0.14 |
| PX | 0.54 | 0.65 | 0.70 | 0.00 | -0.79 | 0.18 | 0.14 | 0.20 | 0.51 |
| PZBR | -0.57 | -0.48 | -0.34 | -0.46 | 0.57 | -0.07 | 0.12 | 0.28 | -0.41 |

| | AVLI | AX | AWHC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | -0.60 | 1.00 | | | | | | | |
| AWHC | 0.66 | -0.52 | 1.00 | | | | | | |
| AWPC | 0.63 | -0.34 | 0.65 | 1.00 | | | | | |
| AWPR | 0.18 | -0.22 | 0.40 | 0.74 | 1.00 | | | | |
| AWP30 | 0.37 | -0.23 | 0.50 | 0.78 | 0.82 | 1.00 | | | |
| AWP60 | 0.06 | 0.07 | 0.12 | 0.41 | 0.57 | 0.65 | 1.00 | | |
| CD | 0.41 | -0.41 | 0.59 | 0.70 | 0.52 | 0.34 | 0.20 | 1.00 | |
| CG | -0.53 | 0.50 | -0.44 | -0.56 | -0.42 | -0.33 | -0.18 | -0.59 | 1.00 |
| CLLI | 0.93 | -0.49 | 0.72 | 0.57 | 0.06 | 0.24 | -0.06 | 0.48 | -0.50 |
| CN | -0.40 | 0.47 | -0.43 | -0.58 | -0.53 | -0.51 | -0.33 | -0.48 | 0.80 |
| CON | 0.58 | -0.47 | 0.58 | 0.83 | 0.72 | 0.66 | 0.46 | 0.70 | -0.58 |
| CR | 0.59 | -0.43 | 0.53 | 0.32 | 0.01 | 0.04 | -0.26 | 0.26 | -0.49 |
| CX | 0.53 | -0.20 | 0.43 | 0.19 | -0.24 | -0.09 | -0.23 | 0.21 | -0.41 |
| MM | -0.40 | 0.31 | 0.03 | -0.41 | -0.37 | -0.31 | -0.23 | -0.19 | 0.26 |
| MP | -0.22 | 0.12 | 0.08 | -0.11 | -0.18 | -0.01 | 0.03 | -0.07 | 0.01 |
| MR | 0.78 | -0.48 | 0.57 | 0.72 | 0.44 | 0.62 | 0.21 | 0.43 | -0.41 |
| PD | 0.27 | -0.32 | 0.39 | 0.74 | 0.68 | 0.58 | 0.44 | 0.80 | -0.38 |
| PE | -0.51 | 0.33 | -0.49 | -0.42 | -0.47 | -0.56 | -0.47 | -0.13 | 0.48 |
| POLI | 0.59 | -0.20 | 0.62 | 0.38 | -0.07 | 0.04 | -0.23 | 0.38 | -0.16 |
| PR | -0.14 | 0.17 | -0.07 | -0.34 | -0.56 | -0.54 | -0.37 | -0.14 | 0.34 |
| PX | -0.52 | 0.39 | -0.54 | -0.42 | -0.46 | -0.68 | -0.29 | -0.07 | 0.31 |
| PZBR | 0.52 | -0.33 | 0.41 | 0.31 | 0.30 | 0.30 | 0.55 | 0.32 | -0.44 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | -0.38 | 1.00 | | | | | | | |
| COM | 0.47 | -0.60 | 1.00 | | | | | | |
| CR | 0.64 | -0.49 | 0.34 | 1.00 | | | | | |
| CX | 0.73 | -0.26 | 0.04 | 0.58 | 1.00 | | | | |
| MM | -0.19 | 0.27 | -0.50 | -0.25 | 0.06 | 1.00 | | | |
| MP | -0.14 | 0.13 | -0.24 | -0.38 | -0.08 | 0.74 | 1.00 | | |
| MR | 0.65 | -0.37 | 0.77 | 0.39 | 0.28 | -0.60 | -0.34 | 1.00 | |
| PD | 0.23 | -0.48 | 0.83 | 0.12 | -0.08 | -0.38 | -0.18 | 0.53 | 1.00 |
| PE | -0.37 | 0.49 | -0.48 | -0.16 | -0.04 | 0.26 | 0.02 | -0.46 | -0.13 |
| POLI | 0.78 | -0.04 | 0.22 | 0.49 | 0.73 | 0.11 | -0.01 | 0.38 | 0.12 |
| PR | 0.05 | 0.34 | -0.42 | 0.13 | 0.31 | 0.37 | 0.14 | -0.37 | -0.36 |
| PX | -0.38 | 0.39 | -0.49 | -0.23 | -0.09 | 0.28 | 0.11 | -0.67 | -0.24 |
| PZBR | 0.42 | -0.31 | 0.50 | 0.16 | 0.10 | -0.24 | -0.12 | 0.40 | 0.25 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | 0.08 | 1.00 | | | |
| PR | 0.59 | 0.39 | 1.00 | | |
| PX | 0.77 | -0.05 | 0.68 | 1.00 | |
| PZBR | -0.72 | 0.06 | -0.44 | -0.47 | 1.00 |

TABLE 12

CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON

POOLED DATA FROM SHIPS CV1

| | MC | FMC | MSPA | CRF | P/MHCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.87 | 1.00 | | | | | | | |
| MSPA | 0.81 | 0.95 | 1.00 | | | | | | |
| CRF | 0.39 | -0.10 | -0.04 | 1.00 | | | | | |
| P/MHCS | -0.81 | -0.91 | -0.73 | 0.14 | 1.00 | | | | |
| AD | 0.37 | -0.03 | -0.23 | 0.63 | -0.27 | 1.00 | | | |
| AG | 0.80 | 0.95 | 1.00 | -0.07 | -0.73 | -0.25 | 1.00 | | |
| AN | 0.71 | 0.93 | 0.99 | -0.21 | -0.70 | -0.37 | 0.99 | 1.00 | |
| AR | 0.65 | 0.87 | 0.97 | -0.20 | -0.60 | -0.46 | 0.97 | 0.99 | 1.00 |
| AVLI | -0.67 | -0.88 | -0.98 | 0.19 | 0.62 | 0.44 | -0.98 | -0.99 | -1.00 |
| AX | 1.00 | 0.87 | 0.81 | 0.39 | -0.81 | 0.37 | 0.80 | 0.71 | 0.65 |
| AWMC | 0.18 | 0.17 | -0.15 | -0.18 | -0.56 | 0.65 | -0.15 | -0.18 | -0.30 |
| AWPC | 0.42 | 0.02 | -0.18 | 0.65 | -0.30 | 1.00 | -0.19 | -0.33 | -0.42 |
| AWPR | 0.34 | -0.03 | -0.24 | 0.55 | -0.30 | 0.99 | -0.27 | -0.39 | -0.49 |
| AWP30 | 0.50 | 0.01 | -0.06 | 0.89 | -0.15 | 0.91 | -0.09 | -0.24 | -0.30 |
| AWP60 | 0.79 | 0.94 | 1.00 | -0.05 | -0.70 | -0.27 | 1.00 | 0.99 | 0.98 |
| CD | 0.50 | 0.08 | -0.10 | 0.72 | -0.32 | 0.99 | -0.11 | -0.25 | -0.34 |
| CG | 0.10 | 0.46 | 0.66 | -0.48 | -0.12 | -0.89 | 0.67 | 0.75 | 0.82 |
| CLLI | 0.82 | 0.47 | 0.33 | 0.67 | -0.61 | 0.84 | 0.31 | 0.17 | 0.09 |
| CN | 0.22 | 0.52 | 0.73 | -0.32 | -0.15 | -0.81 | 0.74 | 0.80 | 0.87 |
| COM | 0.50 | 0.06 | -0.10 | 0.76 | -0.28 | 0.98 | -0.12 | -0.26 | -0.34 |
| CR | 0.43 | 0.74 | 0.54 | -0.61 | -0.87 | -0.04 | 0.55 | 0.59 | 0.51 |
| CX | -0.71 | -0.41 | -0.56 | -0.77 | 0.17 | -0.20 | -0.54 | -0.43 | -0.46 |
| MM | -0.28 | 0.16 | 0.00 | -0.95 | -0.32 | -0.35 | 0.02 | 0.14 | 0.09 |
| MP | 0.15 | 0.04 | -0.27 | -0.00 | -0.45 | 0.77 | -0.27 | -0.32 | -0.44 |
| MR | -0.26 | -0.71 | -0.70 | 0.75 | 0.60 | 0.60 | -0.71 | -0.80 | -0.79 |
| PD | 0.89 | 0.58 | 0.46 | 0.64 | -0.67 | 0.75 | 0.45 | 0.31 | 0.23 |
| PE | 0.48 | -0.00 | -0.11 | 0.86 | -0.17 | 0.94 | -0.13 | -0.28 | -0.34 |
| POLI | 0.82 | 0.47 | 0.33 | 0.67 | -0.61 | 0.84 | 0.31 | 0.17 | 0.09 |
| PR | 0.75 | 0.44 | 0.24 | 0.57 | -0.64 | 0.89 | 0.23 | 0.10 | -0.00 |
| PX | 0.27 | -0.16 | -0.34 | 0.68 | -0.13 | 0.99 | -0.35 | -0.48 | -0.56 |
| PZBR | -0.57 | -0.10 | -0.01 | -0.88 | 0.23 | -0.90 | 0.01 | 0.16 | 0.22 |

| | AVLI | AX | AWHC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | -0.67 | 1.00 | | | | | | | |
| AWHC | 0.28 | 0.18 | 1.00 | | | | | | |
| AWPC | 0.39 | 0.42 | 0.63 | 1.00 | | | | | |
| AWPR | 0.46 | 0.34 | 0.72 | 0.99 | 1.00 | | | | |
| AWP30 | 0.28 | 0.50 | 0.28 | 0.92 | 0.86 | 1.00 | | | |
| AWP60 | -0.98 | 0.79 | -0.19 | -0.22 | -0.30 | -0.10 | 1.00 | | |
| CD | 0.31 | 0.50 | 0.56 | 0.99 | 0.96 | 0.95 | -0.13 | 1.00 | |
| CG | -0.80 | 0.10 | -0.60 | -0.86 | -0.90 | -0.72 | 0.68 | -0.81 | 1.00 |
| CLLI | -0.11 | 0.82 | 0.46 | 0.87 | 0.81 | 0.88 | 0.29 | 0.91 | -0.49 |
| CN | -0.86 | 0.22 | -0.66 | -0.78 | -0.84 | -0.59 | 0.76 | -0.71 | 0.98 |
| COH | 0.32 | 0.50 | 0.50 | 0.99 | 0.95 | 0.97 | -0.13 | 1.00 | -0.80 |
| CR | -0.52 | 0.43 | 0.61 | -0.02 | 0.03 | -0.29 | 0.52 | -0.05 | 0.26 |
| CX | 0.46 | -0.71 | 0.45 | -0.24 | -0.10 | -0.57 | -0.56 | -0.36 | -0.14 |
| MH | -0.09 | -0.28 | 0.49 | -0.37 | -0.25 | -0.70 | -0.00 | -0.45 | 0.23 |
| MP | 0.42 | 0.15 | 0.98 | 0.76 | 0.84 | 0.44 | -0.31 | 0.68 | -0.75 |
| MR | 0.78 | -0.26 | -0.04 | 0.58 | 0.55 | 0.68 | -0.70 | 0.57 | -0.77 |
| PD | -0.26 | 0.89 | 0.39 | 0.78 | 0.71 | 0.82 | 0.43 | 0.84 | -0.36 |
| PE | 0.32 | 0.48 | 0.35 | 0.95 | 0.89 | 1.00 | -0.14 | 0.97 | -0.76 |
| POLI | -0.11 | 0.82 | 0.46 | 0.87 | 0.81 | 0.88 | 0.29 | 0.91 | -0.49 |
| PR | -0.03 | 0.75 | 0.61 | 0.91 | 0.87 | 0.85 | 0.21 | 0.93 | -0.57 |
| PX | 0.54 | 0.27 | 0.57 | 0.98 | 0.98 | 0.92 | -0.37 | 0.97 | -0.93 |
| PZBR | -0.20 | -0.57 | -0.29 | -0.91 | -0.84 | -1.00 | 0.02 | -0.95 | 0.68 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | -0.37 | 1.00 | | | | | | | |
| COM | 0.91 | -0.69 | 1.00 | | | | | | |
| CR | 0.17 | 0.19 | -0.11 | 1.00 | | | | | |
| CX | -0.58 | -0.32 | -0.40 | 0.30 | 1.00 | | | | |
| MM | -0.43 | 0.07 | -0.51 | 0.75 | 0.83 | 1.00 | | | |
| MP | 0.53 | -0.79 | 0.64 | 0.44 | 0.38 | 0.32 | 1.00 | | |
| MR | 0.25 | -0.71 | 0.60 | -0.81 | -0.19 | -0.68 | 0.17 | 1.00 | |
| PD | 0.99 | -0.22 | 0.84 | 0.22 | -0.65 | -0.43 | 0.44 | 0.14 | 1.00 |
| PE | 0.88 | -0.64 | 0.99 | -0.25 | -0.51 | -0.65 | 0.50 | 0.68 | 0.81 |
| POLI | 1.00 | -0.37 | 0.91 | 0.17 | -0.58 | -0.43 | 0.53 | 0.25 | 0.99 |
| PR | 0.98 | -0.47 | 0.92 | 0.26 | -0.43 | -0.30 | 0.67 | 0.24 | 0.96 |
| PX | 0.78 | -0.85 | 0.97 | -0.17 | -0.19 | -0.42 | 0.72 | 0.71 | 0.68 |
| PZBR | -0.91 | 0.54 | -0.97 | 0.23 | 0.61 | 0.69 | -0.43 | -0.62 | -0.86 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | 0.88 | 1.00 | | | |
| PR | 0.86 | 0.98 | 1.00 | | |
| PX | 0.94 | 0.78 | 0.82 | 1.00 | |
| PZBR | -0.99 | -0.91 | -0.88 | -0.90 | 1.00 |

TABLE 13

CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON

POOLED DATA FROM SHIPS CV2

| | MC | FMC | MSPA | CRP | P/NMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.68 | 1.00 | | | | | | | |
| MSPA | -0.96 | -0.70 | 1.00 | | | | | | |
| CRP | -0.42 | -0.48 | 0.18 | 1.00 | | | | | |
| P/NMCS | 0.97 | 0.69 | -1.00 | -0.22 | 1.00 | | | | |
| AD | -0.30 | -0.17 | 0.54 | -0.71 | -0.51 | 1.00 | | | |
| AG | -0.41 | -0.77 | 0.59 | -0.18 | -0.56 | 0.68 | 1.00 | | |
| AN | -0.58 | -0.36 | 0.77 | -0.47 | -0.75 | 0.95 | 0.71 | 1.00 | |
| AR | -0.96 | -0.78 | 0.99 | 0.25 | -0.99 | 0.50 | 0.65 | 0.74 | 1.00 |
| AVLI | -0.96 | -0.67 | 1.00 | 0.16 | -1.00 | 0.56 | 0.59 | 0.79 | 0.99 |
| AX | -0.96 | -0.74 | 1.00 | 0.20 | -1.00 | 0.53 | 0.63 | 0.77 | 1.00 |
| AWMC | 0.31 | 0.57 | -0.11 | -0.97 | 0.13 | 0.70 | 0.04 | 0.50 | -0.19 |
| AWPC | -0.82 | -0.47 | 0.93 | -0.17 | -0.92 | 0.79 | 0.60 | 0.94 | 0.89 |
| AWPR | -0.82 | -0.31 | 0.90 | -0.13 | -0.89 | 0.69 | 0.37 | 0.85 | 0.83 |
| AWP30 | -0.80 | -0.36 | 0.90 | -0.21 | -0.89 | 0.77 | 0.49 | 0.92 | 0.85 |
| AWP60 | -0.99 | -0.75 | 0.98 | 0.35 | -0.99 | 0.39 | 0.53 | 0.65 | 0.99 |
| CD | -0.62 | 0.00 | 0.71 | -0.35 | -0.71 | 0.71 | 0.18 | 0.81 | 0.62 |
| CG | -0.98 | -0.66 | 1.00 | 0.22 | -1.00 | 0.50 | 0.52 | 0.74 | 0.98 |
| CLLI | -0.94 | -0.62 | 0.99 | 0.09 | -0.99 | 0.61 | 0.57 | 0.82 | 0.97 |
| CN | -0.98 | -0.64 | 0.99 | 0.25 | -1.00 | 0.47 | 0.49 | 0.72 | 0.98 |
| COM | -0.62 | 0.15 | 0.59 | -0.05 | -0.61 | 0.34 | -0.20 | 0.49 | 0.48 |
| CR | -0.94 | -0.63 | 1.00 | 0.10 | -0.99 | 0.60 | 0.58 | 0.82 | 0.98 |
| CX | -0.94 | -0.63 | 1.00 | 0.10 | -0.99 | 0.60 | 0.58 | 0.82 | 0.98 |
| MM | -0.50 | -0.07 | 0.68 | -0.56 | -0.66 | 0.91 | 0.43 | 0.94 | 0.60 |
| MP | 0.90 | 0.34 | -0.91 | -0.09 | 0.92 | -0.50 | -0.25 | -0.72 | -0.85 |
| MR | -0.98 | -0.58 | 0.98 | 0.27 | -0.98 | 0.43 | 0.40 | 0.68 | 0.95 |
| PD | -0.47 | 0.00 | 0.64 | -0.58 | -0.62 | 0.89 | 0.36 | 0.91 | 0.55 |
| PE | -0.98 | -0.75 | 0.99 | 0.32 | -0.99 | 0.43 | 0.56 | 0.68 | 0.99 |
| POLI | -0.93 | -0.62 | 0.99 | 0.06 | -0.99 | 0.64 | 0.60 | 0.84 | 0.97 |
| PR | -0.94 | -0.63 | 1.00 | 0.10 | -0.99 | 0.60 | 0.58 | 0.82 | 0.98 |
| PX | -0.47 | -0.79 | 0.65 | -0.16 | -0.61 | 0.69 | 1.00 | 0.74 | 0.70 |
| PZBR | 0.94 | 0.66 | -0.82 | -0.69 | 0.84 | 0.04 | -0.19 | -0.27 | -0.83 |

| | AVLI | AX | AWMC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | 1.00 | 1.00 | | | | | | | |
| AWMC | -0.07 | -0.14 | 1.00 | | | | | | |
| AWPC | 0.94 | 0.92 | 0.26 | 1.00 | | | | | |
| AWPR | 0.91 | 0.87 | 0.28 | 0.97 | 1.00 | | | | |
| AWP30 | 0.92 | 0.88 | 0.32 | 0.99 | 0.99 | 1.00 | | | |
| AWP60 | 0.98 | 0.99 | -0.27 | 0.86 | 0.83 | 0.82 | 1.00 | | |
| CD | 0.73 | 0.67 | 0.52 | 0.87 | 0.95 | 0.93 | 0.61 | 1.00 | |
| CG | 1.00 | 0.99 | -0.13 | 0.92 | 0.91 | 0.90 | 0.99 | 0.72 | 1.00 |
| CLLI | 1.00 | 0.99 | 0.00 | 0.97 | 0.94 | 0.94 | 0.96 | 0.78 | 0.99 |
| CN | 0.99 | 0.98 | -0.14 | 0.91 | 0.90 | 0.89 | 0.99 | 0.73 | 1.00 |
| COM | 0.61 | 0.53 | 0.29 | 0.67 | 0.83 | 0.76 | 0.55 | 0.90 | 0.64 |
| CR | 1.00 | 0.99 | -0.02 | 0.96 | 0.93 | 0.94 | 0.97 | 0.77 | 0.99 |
| CX | 1.00 | 0.99 | -0.02 | 0.96 | 0.93 | 0.94 | 0.97 | 0.77 | 0.99 |
| HH | 0.70 | 0.65 | 0.66 | 0.89 | 0.89 | 0.92 | 0.54 | 0.94 | 0.66 |
| HP | -0.92 | -0.88 | -0.08 | -0.91 | -0.97 | -0.93 | -0.88 | -0.89 | -0.93 |
| HR | 0.98 | 0.96 | -0.14 | 0.89 | 0.91 | 0.89 | 0.98 | 0.75 | 0.99 |
| PD | 0.66 | 0.60 | 0.69 | 0.87 | 0.88 | 0.91 | 0.50 | 0.95 | 0.63 |
| PE | 0.99 | 0.99 | -0.24 | 0.87 | 0.84 | 0.84 | 1.00 | 0.62 | 0.99 |
| POLI | 1.00 | 0.98 | 0.03 | 0.97 | 0.94 | 0.95 | 0.95 | 0.78 | 0.99 |
| PR | 1.00 | 0.99 | -0.02 | 0.96 | 0.93 | 0.94 | 0.97 | 0.77 | 0.99 |
| PX | 0.64 | 0.68 | 0.03 | 0.65 | 0.43 | 0.54 | 0.59 | 0.24 | 0.58 |
| PZBR | -0.80 | -0.82 | 0.57 | -0.58 | -0.62 | -0.56 | -0.90 | -0.40 | -0.85 |

| | CLLI | CN | CON | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | 0.99 | 1.00 | | | | | | | |
| CON | 0.65 | 0.66 | 1.00 | | | | | | |
| CR | 1.00 | 0.99 | 0.64 | 1.00 | | | | | |
| CX | 1.00 | 0.99 | 0.64 | 1.00 | 1.00 | | | | |
| MM | 0.75 | 0.65 | 0.70 | 0.74 | 0.74 | 1.00 | | | |
| MP | -0.94 | -0.94 | -0.87 | -0.93 | -0.93 | -0.77 | 1.00 | | |
| MR | 0.97 | 1.00 | 0.72 | 0.97 | 0.97 | 0.64 | -0.96 | 1.00 | |
| PD | 0.72 | 0.62 | 0.73 | 0.71 | 0.71 | 1.00 | -0.76 | 0.62 | 1.00 |
| PE | 0.97 | 0.99 | 0.54 | 0.97 | 0.97 | 0.57 | -0.88 | 0.97 | 0.53 |
| POLI | 1.00 | 0.98 | 0.63 | 1.00 | 1.00 | 0.77 | -0.93 | 0.96 | 0.73 |
| PR | 1.00 | 0.99 | 0.64 | 1.00 | 1.00 | 0.74 | -0.93 | 0.97 | 0.71 |
| PX | 0.62 | 0.54 | -0.14 | 0.63 | 0.63 | 0.47 | -0.32 | 0.46 | 0.40 |
| PZBR | -0.77 | -0.87 | -0.53 | -0.78 | -0.78 | -0.21 | 0.77 | -0.88 | -0.19 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | 0.96 | 1.00 | | | |
| PR | 0.97 | 1.00 | 1.00 | | |
| PX | 0.61 | 0.65 | 0.63 | 1.00 | |
| PZBR | -0.88 | -0.75 | -0.78 | -0.25 | 1.00 |

## TABLE 14

## CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON POOLED DATA FROM SHIPS CV3

| | MC | FMC | MSPA | CRF | P/NMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.96 | 1.00 | | | | | | | |
| MSPA | 0.45 | 0.48 | 1.00 | | | | | | |
| CRF | -0.08 | 0.01 | 0.16 | 1.00 | | | | | |
| P/NMCS | 0.06 | 0.02 | 0.31 | 0.12 | 1.00 | | | | |
| AD | 0.00 | -0.16 | 0.48 | 0.35 | 0.45 | 1.00 | | | |
| AG | 0.29 | 0.29 | 0.95 | 0.08 | 0.54 | 0.58 | 1.00 | | |
| AN | 0.34 | 0.34 | 0.96 | 0.11 | 0.53 | 0.58 | 1.00 | 1.00 | |
| AR | 0.12 | 0.07 | 0.73 | 0.14 | -0.19 | 0.61 | 0.64 | 0.65 | 1.00 |
| AVLI | 0.76 | 0.77 | 0.54 | 0.52 | -0.10 | 0.25 | 0.31 | 0.38 | 0.42 |
| AX | 0.10 | 0.10 | 0.76 | 0.05 | -0.24 | 0.43 | 0.66 | 0.66 | 0.97 |
| AWMC | 0.20 | 0.26 | 0.52 | -0.33 | 0.69 | -0.02 | 0.67 | 0.64 | -0.07 |
| AWPC | 0.24 | 0.19 | 0.61 | 0.59 | 0.73 | 0.80 | 0.68 | 0.70 | 0.33 |
| AWPR | 0.23 | 0.13 | 0.64 | 0.46 | 0.72 | 0.88 | 0.73 | 0.75 | 0.42 |
| AWP30 | 0.55 | 0.71 | 0.66 | 0.57 | 0.19 | 0.01 | 0.49 | 0.54 | 0.21 |
| AWP60 | 0.78 | 0.72 | 0.78 | 0.31 | 0.25 | 0.55 | 0.67 | 0.71 | 0.56 |
| CD | 0.22 | 0.13 | 0.42 | 0.72 | 0.46 | 0.83 | 0.42 | 0.46 | 0.37 |
| CG | 0.50 | 0.57 | -0.20 | 0.23 | -0.65 | -0.47 | -0.49 | -0.43 | -0.12 |
| CLLI | 0.48 | 0.49 | 0.30 | 0.79 | 0.32 | 0.38 | 0.20 | 0.26 | 0.05 |
| CN | 0.50 | 0.57 | -0.20 | 0.23 | -0.65 | -0.47 | -0.49 | -0.43 | -0.12 |
| COM | 0.09 | 0.03 | 0.40 | 0.75 | 0.57 | 0.82 | 0.45 | 0.48 | 0.31 |
| CR | -0.48 | -0.23 | -0.13 | 0.15 | -0.33 | -0.62 | -0.19 | -0.21 | -0.17 |
| CX | -0.25 | -0.01 | 0.09 | 0.23 | -0.50 | -0.54 | -0.07 | -0.08 | 0.10 |
| MN | -0.22 | -0.27 | -0.25 | -0.90 | -0.41 | -0.39 | -0.20 | -0.25 | -0.00 |
| MP | -0.12 | -0.24 | -0.32 | -0.95 | 0.01 | -0.24 | -0.16 | -0.20 | -0.25 |
| MR | -0.53 | -0.52 | 0.19 | 0.71 | 0.46 | 0.66 | 0.32 | 0.31 | 0.24 |
| PD | 0.18 | 0.10 | 0.45 | 0.74 | 0.38 | 0.85 | 0.44 | 0.47 | 0.46 |
| PE | 0.71 | 0.62 | 0.21 | -0.52 | -0.49 | -0.16 | 0.03 | 0.06 | 0.32 |
| POLI | 0.45 | 0.36 | 0.76 | 0.43 | 0.15 | 0.79 | 0.67 | 0.71 | 0.80 |
| PR | 0.25 | 0.39 | -0.50 | 0.17 | -0.44 | -0.76 | -0.69 | -0.65 | -0.60 |
| PX | 0.31 | 0.29 | 0.94 | 0.24 | 0.55 | 0.70 | 0.98 | 0.98 | 0.67 |
| PZBR | 0.12 | 0.06 | 0.46 | 0.32 | 0.95 | 0.68 | 0.64 | 0.65 | 0.06 |

| | AVLI | AX | AWMC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | 0.35 | 1.00 | | | | | | | |
| AWMC | -0.17 | 0.05 | 1.00 | | | | | | |
| AWPC | 0.47 | 0.20 | 0.28 | 1.00 | | | | | |
| AWPR | 0.40 | 0.28 | 0.30 | 0.98 | 1.00 | | | | |
| AWP30 | 0.77 | 0.26 | 0.30 | 0.50 | 0.37 | 1.00 | | | |
| AWP60 | 0.87 | 0.47 | 0.17 | 0.70 | 0.71 | 0.67 | 1.00 | | |
| CD | 0.58 | 0.18 | -0.13 | 0.91 | 0.89 | 0.40 | 0.69 | 1.00 | |
| CG | 0.62 | -0.12 | -0.55 | -0.32 | -0.42 | 0.36 | 0.19 | -0.07 | 1.00 |
| CLLI | 0.79 | -0.08 | -0.12 | 0.73 | 0.62 | 0.70 | 0.69 | 0.82 | 0.37 |
| CM | 0.62 | -0.12 | -0.55 | -0.32 | -0.42 | 0.36 | 0.19 | -0.07 | 1.00 |
| COM | 0.47 | 0.13 | -0.03 | 0.94 | 0.91 | 0.39 | 0.60 | 0.98 | -0.20 |
| CR | -0.27 | 0.03 | 0.06 | -0.45 | -0.55 | 0.20 | -0.54 | -0.53 | 0.11 |
| CX | 0.04 | 0.29 | -0.05 | -0.39 | -0.49 | 0.39 | -0.26 | -0.41 | 0.32 |
| MM | -0.62 | 0.11 | 0.09 | -0.76 | -0.63 | -0.67 | -0.52 | -0.82 | -0.21 |
| MP | -0.70 | -0.20 | 0.28 | -0.53 | -0.39 | -0.74 | -0.45 | -0.65 | -0.40 |
| MR | -0.04 | 0.15 | -0.04 | 0.67 | 0.64 | 0.12 | 0.05 | 0.66 | -0.50 |
| PD | 0.59 | 0.27 | -0.18 | 0.89 | 0.87 | 0.40 | 0.69 | 0.99 | -0.06 |
| PE | 0.42 | 0.33 | -0.09 | -0.32 | -0.24 | 0.02 | 0.41 | -0.24 | 0.48 |
| POLI | 0.74 | 0.68 | -0.05 | 0.74 | 0.77 | 0.47 | 0.89 | 0.80 | 0.02 |
| PR | 0.25 | -0.55 | -0.35 | -0.45 | -0.50 | 0.25 | -0.19 | -0.30 | 0.85 |
| PX | 0.42 | 0.64 | 0.54 | 0.80 | 0.84 | 0.53 | 0.75 | 0.61 | -0.43 |
| PZBR | 0.12 | -0.04 | 0.54 | 0.91 | 0.90 | 0.29 | 0.47 | 0.70 | -0.58 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | 0.37 | 1.00 | | | | | | | |
| COM | 0.79 | -0.20 | 1.00 | | | | | | |
| CR | -0.30 | 0.11 | -0.43 | 1.00 | | | | | |
| CX | -0.16 | 0.32 | -0.37 | 0.93 | 1.00 | | | | |
| MM | -0.95 | -0.21 | -0.84 | 0.12 | 0.05 | 1.00 | | | |
| MP | -0.81 | -0.40 | -0.64 | -0.20 | -0.37 | 0.87 | 1.00 | | |
| MR | 0.36 | -0.50 | 0.77 | 0.06 | -0.02 | -0.58 | -0.53 | 1.00 | |
| PD | 0.79 | -0.06 | 0.97 | -0.48 | -0.34 | -0.80 | -0.68 | 0.69 | 1.00 |
| PE | -0.14 | 0.48 | -0.40 | -0.38 | -0.12 | 0.42 | 0.30 | -0.80 | -0.23 |
| POLI | 0.58 | 0.02 | 0.72 | -0.50 | -0.23 | -0.49 | -0.51 | 0.35 | 0.83 |
| PR | 0.24 | 0.85 | -0.35 | 0.35 | 0.37 | -0.18 | -0.26 | -0.47 | -0.33 |
| PX | 0.36 | -0.43 | 0.62 | -0.29 | -0.15 | -0.36 | -0.30 | 0.43 | 0.62 |
| PZBR | 0.51 | -0.58 | 0.78 | -0.44 | -0.52 | -0.57 | -0.20 | 0.60 | 0.65 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | 0.25 | 1.00 | | | |
| PR | 0.13 | -0.44 | 1.00 | | |
| PX | -0.01 | 0.79 | -0.67 | 1.00 | |
| PZBR | -0.44 | 0.44 | -0.52 | 0.71 | 1.00 |

## TABLE 15

## CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON POOLED DATA FROM SHIPS CV4

| | MC | FMC | MSFA | CRP | P/NMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.39 | 1.00 | | | | | | | |
| MSFA | 0.02 | 0.47 | 1.00 | | | | | | |
| CRP | -0.17 | -0.09 | -0.03 | 1.00 | | | | | |
| P/NMCS | -0.07 | -0.13 | -0.80 | -0.18 | 1.00 | | | | |
| AD | -0.32 | 0.15 | -0.10 | -0.58 | 0.28 | 1.00 | | | |
| AG | -0.09 | 0.22 | 0.02 | -0.83 | 0.13 | 0.60 | 1.00 | | |
| AN | -0.25 | 0.38 | 0.36 | -0.64 | -0.11 | 0.46 | 0.90 | 1.00 | |
| AR | -0.04 | 0.63 | 0.63 | 0.34 | -0.34 | -0.40 | -0.09 | 0.31 | 1.00 |
| AVLI | 0.06 | 0.63 | 0.38 | 0.29 | -0.10 | -0.43 | 0.00 | 0.32 | 0.94 |
| AX | 0.15 | 0.76 | 0.57 | 0.13 | -0.21 | -0.33 | 0.07 | 0.40 | 0.96 |
| AWMC | -0.05 | -0.73 | -0.65 | -0.25 | 0.40 | 0.32 | -0.04 | -0.40 | -0.98 |
| AWPC | -0.72 | -0.53 | -0.46 | -0.08 | 0.23 | 0.54 | 0.33 | 0.20 | -0.49 |
| AWPR | -0.28 | -0.47 | -0.74 | -0.38 | 0.51 | 0.59 | 0.47 | 0.13 | -0.77 |
| AWP30 | -0.37 | -0.73 | -0.85 | -0.11 | 0.57 | 0.28 | 0.18 | -0.13 | -0.75 |
| AWP60 | -0.28 | -0.44 | -0.27 | -0.59 | 0.05 | 0.38 | 0.74 | 0.54 | -0.48 |
| CD | -0.14 | -0.16 | -0.01 | -0.38 | -0.32 | 0.57 | 0.52 | 0.34 | -0.50 |
| CG | 0.17 | -0.26 | 0.30 | 0.43 | -0.30 | -0.65 | -0.79 | -0.64 | 0.13 |
| CLLI | -0.11 | 0.53 | 0.62 | 0.47 | -0.38 | -0.46 | -0.22 | 0.19 | 0.99 |
| CN | 0.42 | 0.37 | 0.62 | 0.13 | -0.41 | -0.20 | -0.50 | -0.34 | 0.26 |
| COM | -0.35 | -0.35 | -0.42 | -0.10 | 0.03 | 0.43 | 0.41 | 0.21 | -0.49 |
| CR | -0.44 | -0.07 | 0.01 | 0.82 | 0.09 | -0.45 | -0.69 | -0.41 | 0.50 |
| CX | 0.02 | 0.52 | 0.52 | 0.73 | -0.41 | -0.35 | -0.61 | -0.28 | 0.71 |
| MM | 0.34 | -0.34 | -0.16 | -0.21 | 0.30 | -0.23 | -0.33 | -0.46 | -0.36 |
| MP | -0.14 | -0.47 | -0.25 | -0.61 | 0.45 | 0.36 | 0.21 | 0.02 | -0.58 |
| MR | 0.10 | -0.25 | -0.49 | 0.58 | -0.02 | -0.15 | -0.41 | -0.59 | -0.34 |
| PD | -0.38 | -0.39 | -0.25 | -0.00 | -0.19 | 0.39 | 0.28 | 0.13 | -0.47 |
| PE | -0.04 | 0.03 | 0.65 | 0.64 | -0.82 | -0.47 | -0.64 | -0.34 | 0.41 |
| POLI | -0.06 | 0.01 | 0.48 | 0.71 | -0.56 | -0.38 | -0.82 | -0.58 | 0.28 |
| PR | 0.07 | -0.12 | 0.65 | 0.26 | -0.62 | -0.67 | -0.46 | -0.18 | 0.43 |
| PX | -0.23 | 0.25 | 0.95 | 0.03 | -0.81 | -0.14 | 0.04 | 0.41 | 0.62 |
| PZBR | 0.12 | 0.24 | 0.03 | -0.88 | 0.04 | 0.65 | 0.95 | 0.77 | -0.25 |

| | AVLI | AX | AWHC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | 0.96 | 1.00 | | | | | | | |
| AWHC | -0.93 | -0.96 | 1.00 | | | | | | |
| AWPC | -0.47 | -0.60 | 0.48 | 1.00 | | | | | |
| AWPR | -0.63 | -0.73 | 0.72 | 0.83 | 1.00 | | | | |
| AWP30 | -0.59 | -0.76 | 0.76 | 0.81 | 0.91 | 1.00 | | | |
| AWP60 | -0.40 | -0.44 | 0.39 | 0.69 | 0.75 | 0.63 | 1.00 | | |
| CD | -0.56 | -0.51 | 0.35 | 0.62 | 0.61 | 0.36 | 0.71 | 1.00 | |
| CG | -0.01 | 0.02 | 0.01 | -0.57 | -0.66 | -0.39 | -0.61 | -0.58 | 1.00 |
| CLLI | 0.91 | 0.90 | -0.94 | -0.46 | -0.79 | -0.72 | -0.53 | -0.52 | 0.23 |
| CW | 0.06 | 0.26 | -0.22 | -0.76 | -0.76 | -0.78 | -0.75 | -0.36 | 0.70 |
| CON | -0.44 | -0.55 | 0.39 | 0.86 | 0.82 | 0.70 | 0.75 | 0.83 | -0.70 |
| CR | 0.46 | 0.32 | -0.34 | -0.09 | -0.44 | -0.14 | -0.62 | -0.68 | 0.45 |
| CX | 0.55 | 0.58 | -0.67 | -0.47 | -0.77 | -0.70 | -0.83 | -0.42 | 0.39 |
| MM | -0.34 | -0.27 | 0.47 | -0.43 | -0.15 | 0.00 | -0.25 | -0.49 | 0.66 |
| MP | -0.57 | -0.50 | 0.66 | 0.15 | 0.35 | 0.37 | 0.28 | -0.04 | 0.16 |
| MR | -0.29 | -0.45 | 0.30 | 0.33 | 0.34 | 0.41 | -0.02 | 0.32 | -0.12 |
| PD | -0.50 | -0.58 | 0.38 | 0.83 | 0.69 | 0.59 | 0.67 | 0.88 | -0.54 |
| PE | 0.15 | 0.19 | -0.37 | -0.30 | -0.67 | -0.56 | -0.48 | -0.06 | 0.61 |
| POLI | 0.03 | 0.08 | -0.20 | -0.32 | -0.64 | -0.50 | -0.70 | -0.24 | 0.72 |
| PR | 0.25 | 0.32 | -0.33 | -0.56 | -0.78 | -0.58 | -0.36 | -0.42 | 0.84 |
| PX | 0.37 | 0.50 | -0.61 | -0.25 | -0.64 | -0.69 | -0.11 | 0.03 | 0.29 |
| PZBR | -0.18 | -0.07 | 0.09 | 0.26 | 0.49 | 0.14 | 0.71 | 0.64 | -0.74 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | 0.28 | 1.00 | | | | | | | |
| COM | -0.49 | -0.76 | 1.00 | | | | | | |
| CR | 0.62 | 0.12 | -0.36 | 1.00 | | | | | |
| CX | 0.77 | 0.58 | -0.45 | 0.66 | 1.00 | | | | |
| MM | -0.34 | 0.45 | -0.61 | -0.03 | -0.26 | 1.00 | | | |
| MP | -0.60 | 0.02 | -0.15 | -0.28 | -0.66 | 0.73 | 1.00 | | |
| MR | -0.27 | -0.27 | 0.56 | 0.09 | 0.13 | -0.34 | -0.51 | 1.00 | |
| PD | -0.44 | -0.60 | 0.96 | -0.32 | -0.33 | -0.60 | -0.19 | 0.59 | 1.00 |
| PE | 0.51 | 0.57 | -0.24 | 0.41 | 0.74 | -0.15 | -0.50 | 0.20 | 0.01 |
| POLI | 0.40 | 0.70 | -0.38 | 0.56 | 0.79 | 0.07 | -0.32 | 0.22 | -0.15 |
| PR | 0.49 | 0.59 | -0.63 | 0.33 | 0.37 | 0.37 | -0.00 | -0.36 | -0.46 |
| PX | 0.53 | 0.42 | -0.30 | 0.12 | 0.43 | -0.22 | -0.21 | -0.49 | -0.12 |
| PZBR | -0.39 | -0.34 | 0.42 | -0.87 | -0.63 | -0.24 | 0.23 | -0.31 | 0.32 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | 0.92 | 1.00 | | | |
| PR | 0.70 | 0.60 | 1.00 | | |
| PX | 0.66 | 0.45 | 0.70 | 1.00 | |
| PZBR | -0.58 | -0.75 | -0.48 | -0.01 | 1.00 |

TABLE 16

CORRELATION MATRIX OF PERFORMANCE VARIABLES BASED ON

POOLED DATA FROM SHIPS CV5

| | MC | FMC | MSFA | CRF | P/MMCS | AD | AG | AN | AR |
|---|---|---|---|---|---|---|---|---|---|
| MC | 1.00 | | | | | | | | |
| FMC | 0.31 | 1.00 | | | | | | | |
| MSFA | 0.20 | 0.27 | 1.00 | | | | | | |
| CRF | 0.38 | 0.35 | 0.01 | 1.00 | | | | | |
| P/MMCS | -0.82 | -0.44 | -0.31 | -0.72 | 1.00 | | | | |
| AD | 0.22 | 0.52 | -0.07 | 0.19 | -0.27 | 1.00 | | | |
| AG | 0.27 | 0.17 | 0.90 | 0.32 | -0.46 | -0.10 | 1.00 | | |
| AN | 0.21 | 0.18 | 0.95 | 0.08 | -0.33 | 0.01 | 0.94 | 1.00 | |
| AR | -0.01 | -0.12 | 0.69 | -0.34 | 0.16 | -0.36 | 0.53 | 0.63 | 1.00 |
| AVLI | 0.04 | -0.01 | -0.61 | 0.37 | -0.20 | 0.23 | -0.44 | -0.54 | -0.45 |
| AX | 0.02 | -0.09 | 0.75 | -0.28 | 0.02 | -0.44 | 0.58 | 0.60 | 0.71 |
| AWMC | -0.72 | -0.43 | 0.18 | -0.48 | 0.67 | -0.41 | 0.12 | 0.18 | 0.49 |
| AWPC | 0.20 | 0.52 | 0.57 | 0.38 | -0.62 | 0.38 | 0.56 | 0.52 | -0.03 |
| AWPR | 0.11 | 0.63 | 0.34 | 0.57 | -0.61 | 0.32 | 0.41 | 0.30 | -0.25 |
| AWP30 | 0.19 | 0.41 | 0.24 | 0.01 | -0.35 | 0.30 | 0.02 | 0.02 | -0.12 |
| AWP60 | -0.04 | 0.27 | 0.02 | -0.20 | 0.14 | -0.42 | -0.19 | -0.26 | 0.08 |
| CD | -0.03 | 0.32 | 0.31 | 0.18 | -0.21 | 0.71 | 0.39 | 0.46 | -0.16 |
| CG | 0.39 | 0.46 | 0.79 | -0.05 | -0.23 | 0.08 | 0.64 | 0.74 | 0.72 |
| CLLI | -0.75 | -0.48 | 0.12 | -0.48 | 0.62 | -0.49 | 0.06 | 0.06 | 0.17 |
| CN | 0.26 | 0.41 | 0.70 | -0.33 | -0.08 | 0.02 | 0.40 | 0.59 | 0.76 |
| COM | -0.42 | 0.14 | 0.01 | 0.24 | 0.05 | 0.15 | 0.22 | 0.18 | -0.21 |
| CR | -0.47 | -0.50 | -0.26 | 0.36 | 0.13 | -0.27 | 0.03 | -0.19 | -0.30 |
| CX | -0.24 | -0.15 | -0.26 | -0.12 | 0.32 | -0.39 | -0.30 | -0.41 | -0.22 |
| MM | -0.25 | -0.24 | 0.22 | -0.95 | 0.54 | -0.10 | -0.11 | 0.13 | 0.36 |
| MP | -0.24 | -0.31 | -0.14 | -0.92 | 0.57 | -0.11 | -0.46 | -0.19 | 0.16 |
| MR | -0.07 | 0.20 | -0.09 | 0.78 | -0.25 | 0.17 | 0.27 | 0.07 | -0.24 |
| PD | -0.05 | 0.43 | 0.24 | 0.29 | -0.20 | 0.68 | 0.34 | 0.38 | -0.29 |
| PE | 0.27 | 0.33 | 0.48 | 0.04 | -0.44 | 0.32 | 0.32 | 0.36 | -0.10 |
| POLI | -0.28 | 0.29 | 0.58 | -0.31 | 0.15 | -0.38 | 0.32 | 0.37 | 0.40 |
| PR | -0.71 | 0.18 | 0.03 | -0.39 | 0.63 | -0.31 | -0.17 | -0.14 | 0.22 |
| PX | -0.12 | 0.65 | 0.63 | -0.18 | -0.07 | 0.15 | 0.38 | 0.47 | 0.34 |
| PZBR | -0.56 | -0.30 | -0.33 | -0.14 | 0.64 | -0.30 | -0.23 | -0.30 | 0.21 |

| | AVLI | AX | AWHC | AWPC | AWPR | AWP30 | AWP60 | CD | CG |
|---|---|---|---|---|---|---|---|---|---|
| AVLI | 1.00 | | | | | | | | |
| AX | -0.79 | 1.00 | | | | | | | |
| AWHC | -0.06 | 0.18 | 1.00 | | | | | | |
| AWPC | 0.05 | 0.18 | -0.14 | 1.00 | | | | | |
| AWPR | 0.24 | -0.06 | -0.19 | 0.91 | 1.00 | | | | |
| AWP30 | -0.03 | 0.26 | -0.30 | 0.67 | 0.55 | 1.00 | | | |
| AWP60 | -0.33 | 0.43 | -0.11 | -0.11 | -0.01 | 0.41 | 1.00 | | |
| CD | 0.06 | -0.24 | 0.08 | 0.61 | 0.51 | 0.13 | -0.63 | 1.00 | |
| CG | -0.53 | 0.52 | 0.02 | 0.20 | 0.03 | 0.03 | 0.09 | 0.15 | 1.00 |
| CLLI | -0.39 | 0.45 | 0.65 | -0.05 | -0.10 | 0.00 | 0.23 | -0.07 | -0.30 |
| CN | -0.46 | 0.55 | 0.09 | 0.19 | -0.02 | 0.18 | 0.21 | -0.01 | 0.89 |
| CON | 0.35 | -0.38 | 0.41 | 0.34 | 0.51 | -0.28 | -0.45 | 0.61 | -0.20 |
| CR | 0.34 | -0.21 | 0.37 | 0.02 | 0.16 | -0.19 | -0.27 | 0.09 | -0.63 |
| CX | -0.41 | 0.32 | -0.18 | -0.36 | -0.25 | 0.11 | 0.71 | -0.58 | -0.33 |
| MH | -0.53 | 0.44 | 0.37 | -0.15 | -0.40 | 0.16 | 0.21 | -0.03 | 0.16 |
| MP | -0.24 | 0.10 | 0.25 | -0.38 | -0.56 | 0.01 | 0.11 | -0.23 | -0.05 |
| MR | 0.41 | -0.42 | 0.01 | 0.16 | 0.41 | -0.39 | -0.39 | 0.36 | -0.10 |
| PD | 0.01 | -0.33 | -0.02 | 0.51 | 0.50 | 0.04 | -0.55 | 0.94 | 0.15 |
| PE | -0.23 | 0.25 | -0.22 | 0.74 | 0.53 | 0.80 | 0.06 | 0.44 | 0.19 |
| POLI | -0.50 | 0.58 | 0.38 | 0.32 | 0.28 | 0.39 | 0.58 | -0.08 | 0.40 |
| PR | -0.24 | 0.28 | 0.49 | -0.10 | 0.04 | 0.08 | 0.62 | -0.25 | 0.00 |
| PX | -0.30 | 0.42 | 0.19 | 0.64 | 0.58 | 0.55 | 0.36 | 0.31 | 0.51 |
| PZBR | 0.25 | -0.19 | 0.65 | -0.53 | -0.36 | -0.54 | 0.03 | -0.21 | -0.15 |

| | CLLI | CN | COM | CR | CX | MM | MP | MR | PD |
|---|---|---|---|---|---|---|---|---|---|
| CLLI | 1.00 | | | | | | | | |
| CN | -0.20 | 1.00 | | | | | | | |
| COM | 0.22 | -0.29 | 1.00 | | | | | | |
| CR | 0.45 | -0.78 | 0.46 | 1.00 | | | | | |
| CX | 0.47 | -0.32 | -0.39 | 0.14 | 1.00 | | | | |
| MM | 0.50 | 0.41 | -0.25 | -0.43 | 0.13 | 1.00 | | | |
| MP | 0.25 | 0.30 | -0.33 | -0.46 | 0.04 | 0.85 | 1.00 | | |
| MR | -0.19 | -0.41 | 0.67 | 0.55 | -0.22 | -0.82 | -0.84 | 1.00 | |
| PD | -0.15 | -0.07 | 0.59 | 0.09 | -0.46 | -0.17 | -0.30 | 0.45 | 1.00 |
| PE | -0.03 | 0.22 | -0.15 | -0.15 | -0.15 | 0.20 | 0.03 | -0.35 | 0.39 |
| POLI | 0.43 | 0.52 | -0.01 | -0.20 | 0.16 | 0.40 | 0.20 | -0.35 | -0.04 |
| PR | 0.58 | 0.18 | 0.18 | -0.01 | 0.44 | 0.32 | 0.20 | -0.10 | -0.20 |
| PX | 0.17 | 0.64 | 0.22 | -0.39 | -0.14 | 0.33 | 0.06 | -0.17 | 0.25 |
| PZBR | 0.29 | -0.21 | 0.30 | 0.40 | 0.07 | -0.09 | -0.09 | 0.38 | -0.20 |

| | PE | POLI | PR | PX | PZBR |
|---|---|---|---|---|---|
| PE | 1.00 | | | | |
| POLI | 0.43 | 1.00 | | | |
| PR | -0.22 | 0.64 | 1.00 | | |
| PX | 0.47 | 0.77 | 0.55 | 1.00 | |
| PZBR | -0.73 | -0.11 | 0.46 | -0.20 | 1.00 |

## APPENDIX C. RAW DATA OBSERVATIONS

Table 17 lists the observations obtained from the five aircraft carriers examined in this study. For security reasons, only the standardized values of the variables, MC and FMC, are listed.

CV1 data are listed in rows 1 through 4, CV2 data are in rows 5 through 8, CV3 data are in rows 9 through 14, CV4 data are in rows 15 through 21, and CV5 data are in rows 22 through 32.

TABLE 17

RAW DATA OBSERVATIONS

| ROW | MC | PMC | MSFA | CRF | P/MMCS |
|---|---|---|---|---|---|
| * 1 * | 0.18092 | 0.95635 | 0.75182 | 0.60750 | 198.00000 |
| * 2 * | 0.60978 | 1.40639 | 0.83227 | 0.69500 | 116.00000 |
| * 3 * | 0.39535 | 1.10636 | 0.75227 | 0.66750 | 135.00000 |
| * 4 * | 0.39535 | 0.95635 | 0.75000 | 0.82250 | 193.00000 |
| * 5 * | 0.60978 | -0.24378 | 0.86818 | 0.65750 | 135.00000 |
| * 6 * | -0.03350 | 0.20627 | 0.87091 | 0.70750 | 127.00000 |
| * 7 * | -0.03350 | -2.19398 | 0.87818 | 0.72250 | 123.00000 |
| * 8 * | 1.89635 | 0.95635 | 0.78364 | 0.69000 | 212.00000 |
| * 9 * | -0.89121 | -0.39379 | 0.75000 | 0.80000 | 68.00000 |
| * 10 * | -0.67679 | -0.24378 | 0.85954 | 0.71500 | 76.00000 |
| * 11 * | -0.24793 | 0.50630 | 0.85000 | 0.81250 | 97.00000 |
| * 12 * | -1.10564 | -0.84384 | 0.86363 | 0.87750 | 81.00000 |
| * 13 * | 0.82421 | 1.40639 | 0.85727 | 0.78500 | 79.00000 |
| * 14 * | 0.39535 | 1.70642 | 0.89545 | 0.84250 | 72.00000 |
| * 15 * | -1.53450 | -0.69383 | 0.81682 | 0.81250 | 204.00000 |
| * 16 * | -1.10564 | -1.59392 | 0.72682 | 0.84000 | 272.00000 |
| * 17 * | -1.32007 | -1.29389 | 0.80045 | 0.68500 | 142.00000 |
| * 18 * | -2.17778 | -1.44390 | 0.76500 | 0.67750 | 311.00000 |
| * 19 * | -1.96335 | -1.74393 | 0.69273 | 0.74750 | 336.00000 |
| * 20 * | -0.89121 | -0.54381 | 0.73182 | 0.68000 | 339.00000 |
| * 21 * | -0.67679 | -1.29389 | 0.75545 | 0.64000 | 294.00000 |
| * 22 * | -0.24793 | 0.05625 | 0.78364 | 0.72500 | 142.00000 |
| * 23 * | -0.03350 | -0.09376 | 0.79545 | 0.51000 | 149.00000 |
| * 24 * | 0.18092 | -0.09376 | 0.85273 | 0.75000 | 89.00000 |
| * 25 * | 0.39535 | 0.95635 | 0.81682 | 0.75750 | 93.00000 |
| * 26 * | 0.60978 | 0.80633 | 0.82182 | 0.74250 | 85.00000 |
| * 27 * | 1.25306 | 0.65631 | 0.83227 | 0.75250 | 61.00000 |
| * 28 * | 1.25306 | 0.35628 | 0.83318 | 0.67500 | 94.00000 |
| * 29 * | 0.82421 | 0.20627 | 0.82863 | 0.72750 | 84.00000 |
| * 30 * | 1.25306 | 0.20627 | 0.83136 | 0.74000 | 77.00000 |
| * 31 * | 0.82421 | 0.05625 | 0.73182 | 0.77000 | 85.00000 |
| * 32 * | 1.03863 | 0.20627 | 0.79545 | 0.78250 | 79.00000 |

| ROW | AD | AG | AN | AR | AVLI |
|---|---|---|---|---|---|
| * 1 * | 1928.00000 | 0.49000 | 0.70000 | 0.81000 | 44809.00000 |
| * 2 * | 4444.00000 | 0.70000 | 0.85000 | 0.84000 | 43967.00000 |
| * 3 * | 7901.00000 | 0.49000 | 0.68000 | 0.80000 | 45051.00000 |
| * 4 * | 7274.00000 | 0.48000 | 0.66000 | 0.80000 | 45062.00000 |
| * 5 * | 9735.00000 | 0.72000 | 0.85000 | 0.89000 | 53790.00000 |
| * 6 * | 3847.00000 | 0.71000 | 0.84000 | 0.89000 | 53940.00000 |
| * 7 * | 3884.00000 | 0.72000 | 0.84000 | 0.90000 | 54260.00000 |
| * 8 * | 1673.00000 | 0.71000 | 0.83000 | 0.85000 | 47439.00000 |
| * 9 * | 1186.00000 | 0.37000 | 0.61000 | 0.79000 | 27548.00000 |
| * 10 * | 3318.00000 | 0.76000 | 0.86000 | 0.90000 | 27385.00000 |
| * 11 * | 3840.00000 | 0.76000 | 0.87000 | 0.80000 | 27677.00000 |
| * 12 * | 7009.00000 | 0.76000 | 0.87000 | 0.93000 | 27880.00000 |
| * 13 * | 5448.00000 | 0.70000 | 0.84000 | 0.89000 | 28246.00000 |
| * 14 * | 2378.00000 | 0.76000 | 0.88000 | 0.90000 | 28372.00000 |
| * 15 * | 1659.00000 | 0.54000 | 0.78000 | 0.88000 | 52070.00000 |
| * 16 * | 1963.00000 | 0.43000 | 0.56000 | 0.78000 | 48002.00000 |
| * 17 * | 5352.00000 | 0.63000 | 0.80000 | 0.79000 | 48015.00000 |
| * 18 * | 7709.00000 | 0.60000 | 0.78000 | 0.79000 | 48113.00000 |
| * 19 * | 3998.00000 | 0.62000 | 0.77000 | 0.79000 | 49203.00000 |
| * 20 * | 7328.00000 | 0.64000 | 0.78000 | 0.80000 | 49412.00000 |
| * 21 * | 2189.00000 | 0.61000 | 0.76000 | 0.80000 | 49397.00000 |
| * 22 * | 2213.00000 | 0.61000 | 0.71000 | 0.97000 | 37055.00000 |
| * 23 * | 4894.00000 | 0.56000 | 0.73000 | 0.98000 | 37084.00000 |
| * 24 * | 3667.00000 | 0.75000 | 0.84000 | 0.97000 | 37270.00000 |
| * 25 * | 8881.00000 | 0.66000 | 0.79000 | 0.88000 | 37270.00000 |
| * 26 * | 7506.00000 | 0.62000 | 0.74000 | 0.96000 | 38022.00000 |
| * 27 * | 3158.00000 | 0.69000 | 0.79000 | 0.97000 | 38177.00000 |
| * 28 * | 4549.00000 | 0.67000 | 0.78000 | 0.98000 | 35472.00000 |
| * 29 * | 3301.00000 | 0.66000 | 0.79000 | 0.96000 | 35622.00000 |
| * 30 * | 7242.00000 | 0.70000 | 0.32000 | 0.97000 | 35605.00000 |
| * 31 * | 5783.00000 | 0.52000 | 0.62000 | 0.80000 | 40274.00000 |
| * 32 * | 6721.00000 | 0.64000 | 0.76000 | 0.97000 | 40950.00000 |

| ROW | AX | AWMC | AWPC | AWPR | AWP30 |
|---|---|---|---|---|---|
| * 1 * | 0.75000 | 311.00000 | 145.00000 | 189.00000 | 0.0 |
| * 2 * | 0.81000 | 347.00000 | 349.00000 | 331.00000 | 46.00000 |
| * 3 * | 0.78000 | 487.00000 | 575.00000 | 577.00000 | 62.00000 |
| * 4 * | 0.78000 | 324.00000 | 536.00000 | 494.00000 | 90.00000 |
| * 5 * | 0.86000 | 202.00000 | 330.00000 | 617.00000 | 110.00000 |
| * 6 * | 0.86000 | 119.00000 | 285.00000 | 630.00000 | 97.00000 |
| * 7 * | 0.87000 | 51.00000 | 262.00000 | 439.00000 | 72.00000 |
| * 8 * | 0.80000 | 126.00000 | 97.00000 | 114.00000 | 8.00000 |
| * 9 * | 0.76000 | 97.00000 | 121.00000 | 182.00000 | 3.00000 |
| * 10 * | 0.87000 | 164.00000 | 154.00000 | 289.00000 | 3.00000 |
| * 11 * | 0.77000 | 185.00000 | 271.00000 | 446.00000 | 38.00000 |
| * 12 * | 0.87000 | 115.00000 | 282.00000 | 484.00000 | 25.00000 |
| * 13 * | 0.83000 | 125.00000 | 245.00000 | 433.00000 | 24.00000 |
| * 14 * | 0.87000 | 144.00000 | 212.00000 | 332.00000 | 69.00000 |
| * 15 * | 0.83000 | 0.0 | 391.00000 | 0.0 | 0.0 |
| * 16 * | 0.76000 | 507.00000 | 500.00000 | 504.00000 | 180.00000 |
| * 17 * | 0.77000 | 377.00000 | 639.00000 | 678.00000 | 136.00000 |
| * 18 * | 0.77000 | 468.00000 | 687.00000 | 714.00000 | 187.00000 |
| * 19 * | 0.77000 | 432.00000 | 829.00000 | 1078.00000 | 329.00000 |
| * 20 * | 0.79000 | 330.00000 | 535.00000 | 783.00000 | 148.00000 |
| * 21 * | 0.79000 | 383.00000 | 350.00000 | 459.00000 | 128.00000 |
| * 22 * | 0.84000 | 168.00000 | 186.00000 | 284.00000 | 25.00000 |
| * 23 * | 0.84000 | 187.00000 | 241.00000 | 237.00000 | 71.00000 |
| * 24 * | 0.88000 | 193.00000 | 389.00000 | 651.00000 | 89.00000 |
| * 25 * | 0.77000 | 75.00000 | 352.00000 | 674.00000 | 70.00000 |
| * 26 * | 0.86000 | 55.00000 | 373.00000 | 643.00000 | 144.00000 |
| * 27 * | 0.86000 | 61.00000 | 342.00000 | 641.00000 | 81.00000 |
| * 28 * | 0.87000 | 90.00000 | 260.00000 | 320.00000 | 84.00000 |
| * 29 * | 0.87000 | 43.00000 | 281.00000 | 391.00000 | 70.00000 |
| * 30 * | 0.88000 | 11.00000 | 295.00000 | 370.00000 | 65.00000 |
| * 31 * | 0.74000 | 0.0 | 263.00000 | 457.00000 | 86.00000 |
| * 32 * | 0.75000 | 111.00000 | 276.00000 | 410.00000 | 40.00000 |

| ROW | AWP60 | CD | CG | CLLI | CN |
|---|---|---|---|---|---|
| * 1 * | 2.00000 | 524.00000 | 0.76000 | 3188.00000 | 0.76000 |
| * 2 * | 46.00000 | 1129.00000 | 0.77000 | 3188.00000 | 0.78000 |
| * 3 * | 0.0 | 1562.00000 | 0.69000 | 3188.00000 | 0.70000 |
| * 4 * | 0.0 | 1570.00000 | 0.70000 | 3188.00000 | 0.72000 |
| * 5 * | 38.00000 | 1439.00000 | 0.83000 | 3362.00000 | 0.86000 |
| * 6 * | 47.00000 | 1443.00000 | 0.87000 | 3362.00000 | 0.91000 |
| * 7 * | 53.00000 | 574.00000 | 0.87000 | 3352.00000 | 0.90000 |
| * 8 * | 0.0 | 168.00000 | 0.55000 | 2930.00000 | 0.62000 |
| * 9 * | 1.00000 | 89.00000 | 0.94000 | 557.00000 | 0.94000 |
| * 10 * | 5.00000 | 60.00000 | 0.82000 | 541.00000 | 0.82000 |
| * 11 * | 8.00000 | 199.00000 | 0.83000 | 569.00000 | 0.83000 |
| * 12 * | 9.00000 | 288.00000 | 0.84000 | 569.00000 | 0.84000 |
| * 13 * | 14.00000 | 241.00000 | 0.92000 | 571.00000 | 0.92000 |
| * 14 * | 12.00000 | 166.00000 | 0.96000 | 571.00000 | 0.96000 |
| * 15 * | 0.0 | 263.00000 | 0.77000 | 3751.00000 | 0.83000 |
| * 16 * | 0.0 | 631.00000 | 0.82000 | 3106.00000 | 0.85000 |
| * 17 * | 147.00000 | 2157.00000 | 0.72000 | 3106.00000 | 0.77000 |
| * 18 * | 84.00000 | 952.00000 | 0.75000 | 3124.00000 | 0.79000 |
| * 19 * | 165.00000 | 1211.00000 | 0.68000 | 3124.00000 | 0.53000 |
| * 20 * | 62.00000 | 1194.00000 | 0.66000 | 3124.00000 | 0.75000 |
| * 21 * | 91.00000 | 453.00000 | 0.78000 | 3143.00000 | 0.80000 |
| * 22 * | 75.00000 | 221.00000 | 0.77000 | 1538.00000 | 0.78000 |
| * 23 * | 54.00000 | 489.00000 | 0.77000 | 1547.00000 | 0.84000 |
| * 24 * | 37.00000 | 793.00000 | 0.77000 | 1574.00000 | 0.78000 |
| * 25 * | 40.00000 | 1021.00000 | 0.80000 | 1453.00000 | 0.81000 |
| * 26 * | 82.00000 | 523.00000 | 0.80000 | 1453.00000 | 0.85000 |
| * 27 * | 79.00000 | [illegible]6.00000 | 0.81000 | 1453.00000 | 0.85000 |
| * 28 * | 78.00000 | 462.00000 | 0.84000 | 1453.00000 | 0.85000 |
| * 29 * | 59.00000 | 318.00000 | 0.80000 | 1455.00000 | 0.84000 |
| * 30 * | 37.00000 | 643.00000 | 0.81000 | 1458.00000 | 0.82000 |
| * 31 * | 57.00000 | 405.00000 | 0.69000 | 1458.00000 | 0.70000 |
| * 32 * | 12.00000 | 649.00000 | 0.80000 | 1368.00000 | 0.82000 |

| ROW | CCM | CR | CX | MM | MP |
|---|---|---|---|---|---|
| * 1 * | 1297.00000 | 0.95000 | 0.94000 | 0.24000 | 0.11000 |
| * 2 * | 2631.00000 | 0.96000 | 0.92000 | 0.19000 | 0.13000 |
| * 3 * | 3514.00000 | 0.96000 | 0.94000 | 0.25000 | 0.23000 |
| * 4 * | 3698.00000 | 0.94000 | 0.92000 | 0.09000 | 0.14000 |
| * 5 * | 2452.00000 | 0.99000 | 0.99000 | 0.24000 | 0.14000 |
| * 6 * | 4077.00000 | 0.99000 | 0.99000 | 0.19000 | 0.12000 |
| * 7 * | 1158.00000 | 0.99000 | 0.99000 | 0.14000 | 0.15000 |
| * 8 * | 595.00000 | 0.84000 | 0.84000 | 0.10000 | 0.20000 |
| * 9 * | 972.00000 | 0.98000 | 0.90000 | 0.10000 | 0.12000 |
| * 10 * | 789.00000 | 0.97000 | 0.89000 | 0.20000 | 0.19000 |
| * 11 * | 2008.00000 | 0.96000 | 0.85000 | 0.02000 | 0.11000 |
| * 12 * | 2574.00000 | 0.96000 | 0.88000 | 0.01000 | 0.05000 |
| * 13 * | 1946.00000 | 0.91000 | 0.80000 | 0.06000 | 0.12000 |
| * 14 * | 1516.00000 | 0.99000 | 0.96000 | 0.03000 | 0.04000 |
| * 15 * | 2730.00000 | 0.96000 | 0.94000 | 0.05000 | 0.07000 |
| * 16 * | 4288.00000 | 0.95000 | 0.91000 | 0.12000 | 0.12000 |
| * 17 * | 7303.00000 | 0.91000 | 0.88000 | 0.05000 | 0.11000 |
| * 18 * | 4426.00000 | 0.94000 | 0.88000 | 0.11000 | 0.19000 |
| * 19 * | 8172.00000 | 0.94000 | 0.86000 | 0.05000 | 0.12000 |
| * 20 * | 5642.00000 | 0.92000 | 0.89000 | 0.06000 | 0.11000 |
| * 21 * | 2564.00000 | 0.92000 | 0.86000 | 0.15000 | 0.17000 |
| * 22 * | 2690.00000 | 0.94000 | 0.90000 | 0.10000 | 0.09000 |
| * 23 * | 2141.00000 | 0.86000 | 0.83000 | 0.38000 | 0.48000 |
| * 24 * | 3864.00000 | 0.98000 | 0.82000 | 0.15000 | 0.06000 |
| * 25 * | 4540.00000 | 0.88000 | 0.81000 | 0.13000 | 0.11000 |
| * 26 * | 1196.00000 | 0.87000 | 0.85000 | 0.14000 | 0.12000 |
| * 27 * | 2864.00000 | 0.86000 | 0.83000 | 0.13000 | 0.11000 |
| * 28 * | 507.00000 | 0.86000 | 0.85000 | 0.22000 | 0.19000 |
| * 29 * | 755.00000 | 0.87000 | 0.85000 | 0.15000 | 0.24000 |
| * 30 * | 1459.00000 | 0.87000 | 0.85000 | 0.17000 | 0.11000 |
| * 31 * | 1949.00000 | 0.94000 | 0.88000 | 0.08000 | 0.14000 |
| * 32 * | 2864.00000 | 0.90000 | 0.74000 | 0.04000 | 0.10000 |

| ROW | MR | PD | PE | POLI | PR |
|---|---|---|---|---|---|
| * 1 * | 0.65000 | 365.00000 | 0.88000 | 276.00000 | 0.94000 |
| * 2 * | 0.62000 | 906.00000 | 0.90000 | 279.00000 | 0.99000 |
| * 3 * | 0.67000 | 822.00000 | 0.91000 | 279.00000 | 1.00000 |
| * 4 * | 0.73000 | 836.00000 | 0.92000 | 279.00000 | 0.99000 |
| * 5 * | 0.76000 | 1150.00000 | 0.93000 | 238.00000 | 0.99000 |
| * 6 * | 0.78000 | 872.00000 | 0.94000 | 237.00000 | 0.99000 |
| * 7 * | 0.77000 | 493.00000 | 0.95000 | 237.00000 | 0.99000 |
| * 8 * | 0.70000 | 300.00000 | 0.87000 | 217.00000 | 0.96000 |
| * 9 * | 0.64000 | 300.00000 | 0.96000 | 132.00000 | 0.98000 |
| * 10 * | 0.63000 | 231.00000 | 0.97000 | 134.00000 | 0.93000 |
| * 11 * | 0.73000 | 601.00000 | 0.95000 | 134.00000 | 0.95000 |
| * 12 * | 0.85000 | 968.00000 | 0.95000 | 137.00000 | 0.93000 |
| * 13 * | 0.62000 | 765.00000 | 0.98000 | 137.00000 | 0.95000 |
| * 14 * | 0.65000 | 571.00000 | 0.97000 | 136.00000 | 0.97000 |
| * 15 * | 0.75000 | 529.00000 | 0.95000 | 278.00000 | 1.00000 |
| * 16 * | 0.84000 | 871.00000 | 0.92000 | 289.00000 | 0.93000 |
| * 17 * | 0.79000 | 1484.00000 | 0.91000 | 261.00000 | 0.92000 |
| * 18 * | 0.72000 | 833.00000 | 0.77000 | 258.00000 | 0.89000 |
| * 19 * | 0.81000 | 1375.00000 | 0.70000 | 228.00000 | 0.80000 |
| * 20 * | 0.79000 | 899.00000 | 0.58000 | 235.00000 | 0.72000 |
| * 21 * | 0.72000 | 372.00000 | 0.72000 | 235.00000 | 0.97000 |
| * 22 * | 0.67000 | 514.00000 | 0.83000 | 213.00000 | 0.99000 |
| * 23 * | 0.61000 | 568.00000 | 0.90000 | 221.00000 | 0.96000 |
| * 24 * | 0.66000 | 818.00000 | 0.95000 | 230.00000 | 0.92000 |
| * 25 * | 0.67000 | 1141.00000 | 0.93000 | 220.00000 | 0.94000 |
| * 26 * | 0.64000 | 648.00000 | 0.95000 | 230.00000 | 0.96000 |
| * 27 * | 0.65000 | 514.00000 | 0.90000 | 230.00000 | 0.94000 |
| * 28 * | 0.63000 | 665.00000 | 0.94000 | 230.00000 | 0.91000 |
| * 29 * | 0.63000 | 593.00000 | 0.93000 | 230.00000 | 0.91000 |
| * 30 * | 0.65000 | 718.00000 | 0.90000 | 176.00000 | 0.88000 |
| * 31 * | 0.65000 | 612.00000 | 0.91000 | 176.00000 | 0.89000 |
| * 32 * | 0.67000 | 747.00000 | 0.88000 | 176.00000 | 0.87000 |

| ROW | FX | PZBR |
|---|---|---|
| * 1 * | 0.830000 | 0.21000 |
| * 2 * | 0.870000 | 0.11000 |
| * 3 * | 0.950000 | 0.09000 |
| * 4 * | 0.950000 | 0.04000 |
| * 5 * | 0.940000 | 0.17000 |
| * 6 * | 0.840000 | 0.15000 |
| * 7 * | 0.940000 | 0.15000 |
| * 8 * | 0.830000 | 0.18000 |
| * 9 * | 0.570000 | 0.04000 |
| * 10 * | 0.710000 | 0.06000 |
| * 11 * | 0.730000 | 0.11000 |
| * 12 * | 0.750000 | 0.09000 |
| * 13 * | 0.720000 | 0.08000 |
| * 14 * | 0.730000 | 0.06000 |
| * 15 * | 0.960000 | 0.11000 |
| * 16 * | 0.620000 | 0.04000 |
| * 17 * | 0.900000 | 0.28000 |
| * 18 * | 0.800000 | 0.20000 |
| * 19 * | 0.600000 | 0.20000 |
| * 20 * | 0.580000 | 0.28000 |
| * 21 * | 0.720000 | 0.23000 |
| * 22 * | 0.880000 | 0.16000 |
| * 23 * | 0.910000 | 0.11000 |
| * 24 * | 0.910000 | 0.10000 |
| * 25 * | 0.930000 | 0.09000 |
| * 26 * | 0.940000 | 0.09000 |
| * 27 * | 0.930000 | 0.09000 |
| * 28 * | 0.900000 | 0.10000 |
| * 29 * | 0.890000 | 0.06000 |
| * 30 * | 0.880000 | 0.08000 |
| * 31 * | 0.850000 | 0.09000 |
| * 32 * | 0.870000 | 0.12000 |

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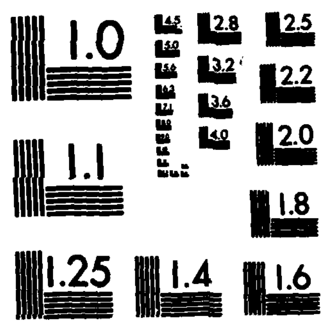


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